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GEOPHYSICS

A Journal of General and Applied Geophysics

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The Society of Exploration Geophysicists

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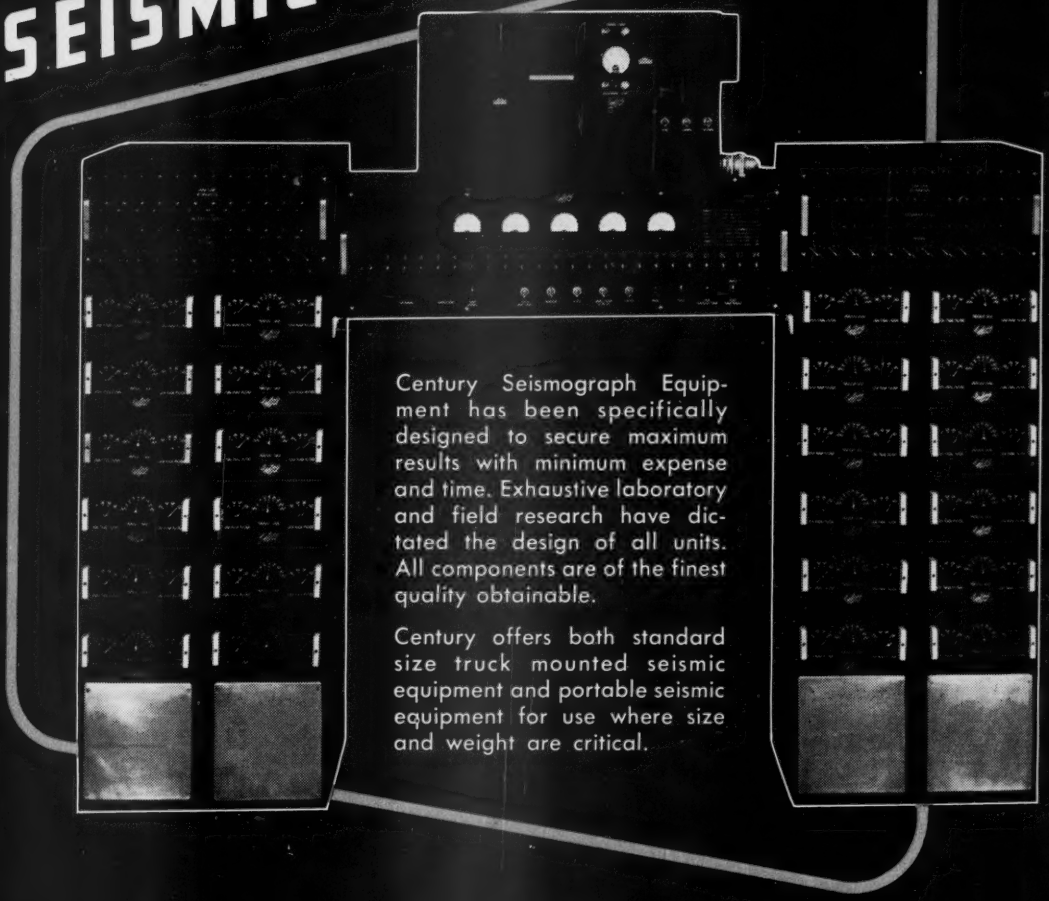

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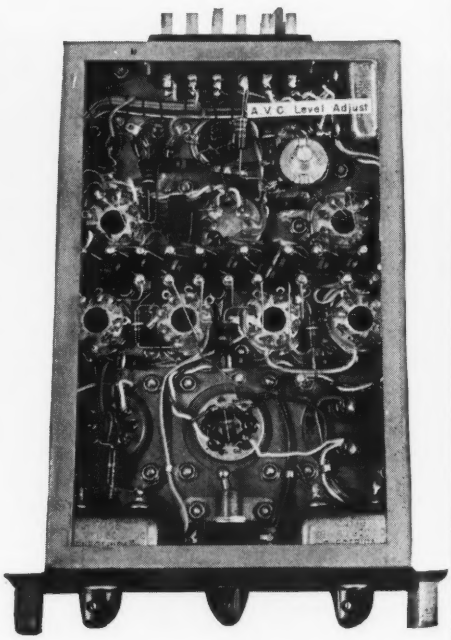

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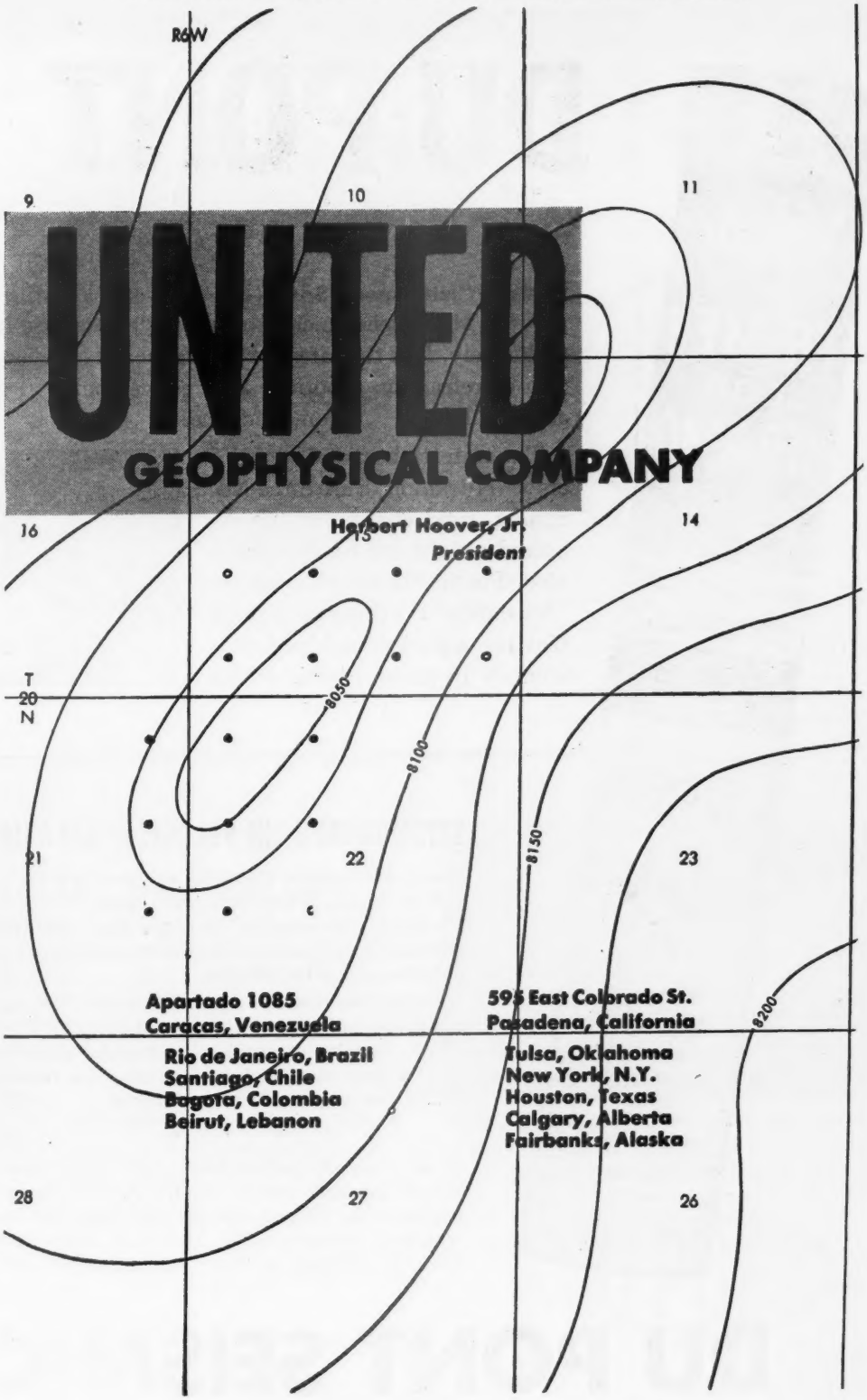

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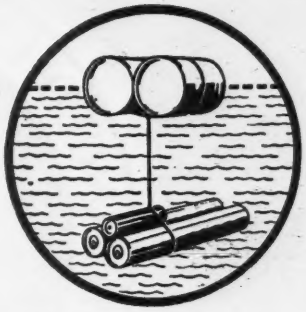

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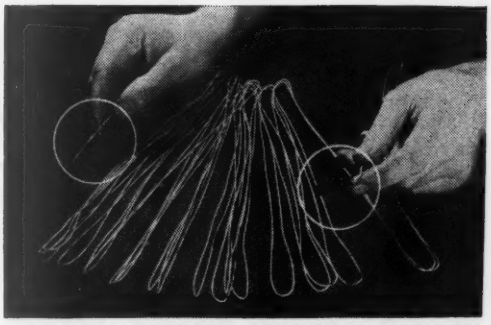

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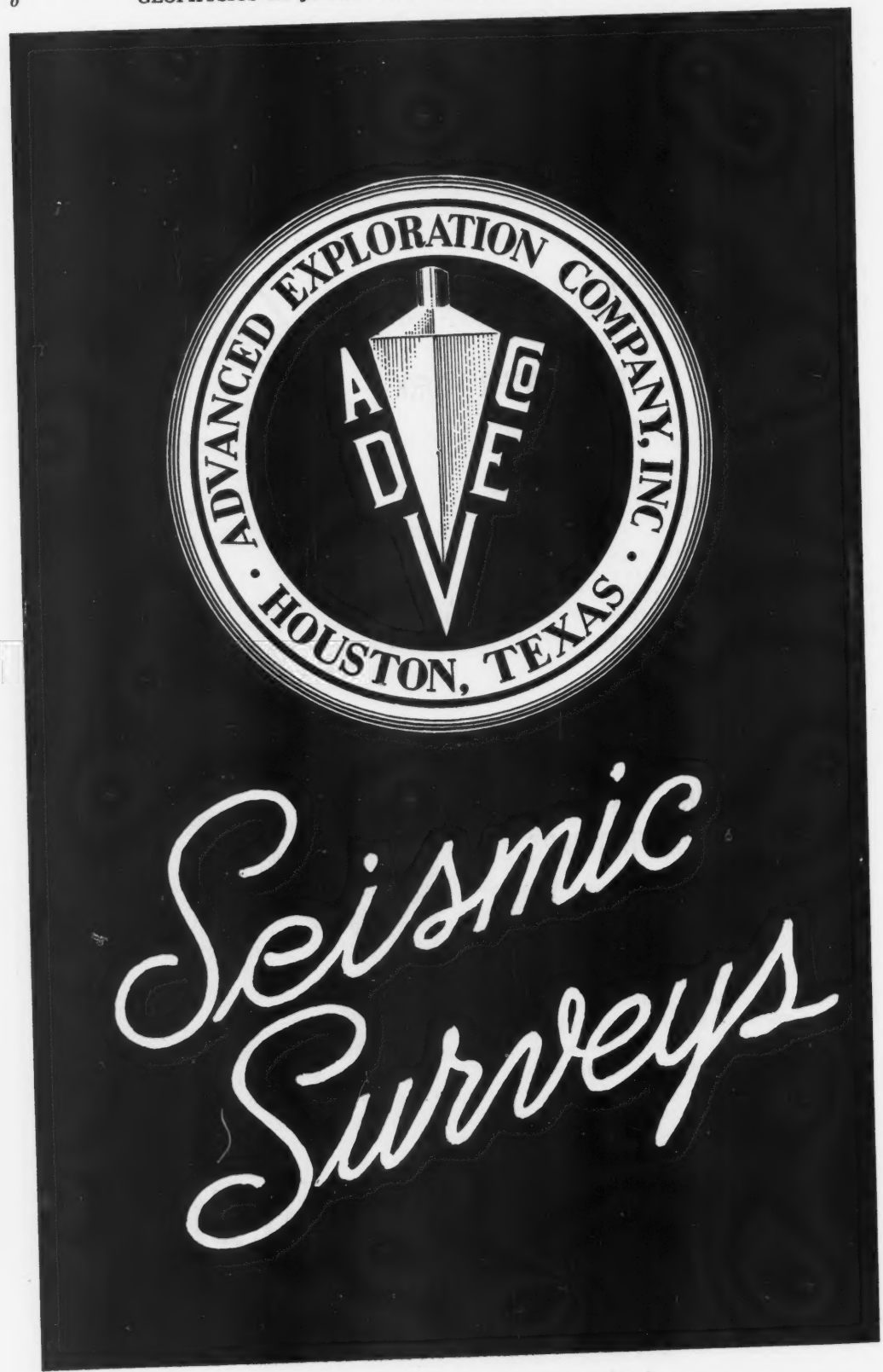
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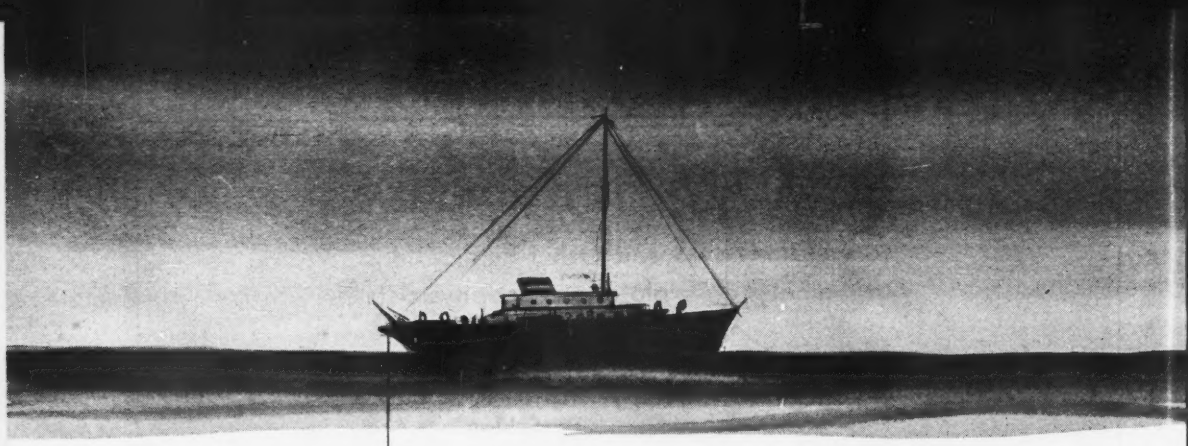

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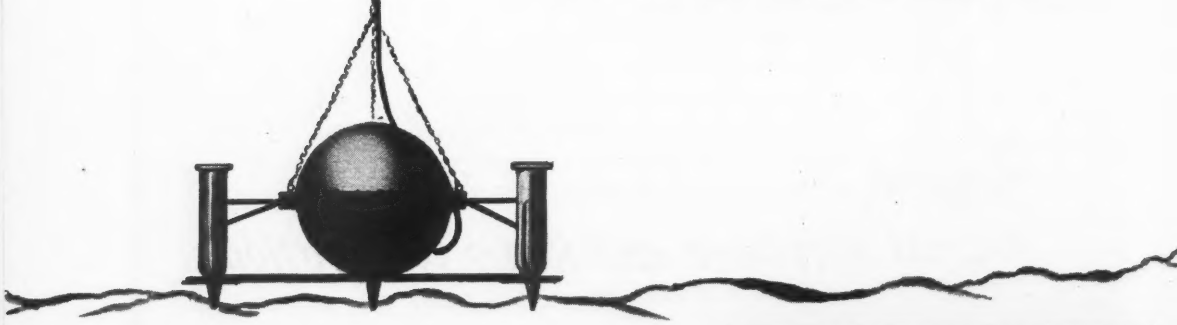

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MICROCARDS, A NEW METHOD OF PUBLICATION*

C. HEWITT DIX†

The recently introduced system of microcards promises to fill such an important combination of vital needs in the field of publication as to appear to be potentially revolutionary. In view of this development and its consequent advantages to geophysicists and geologists, it has been thought timely to present in *Geophysics* a description of the microcard method with some comments on its possibilities.

The form of the microcard is essentially that of an ordinary 3×5-inch library catalog card such as is almost universally used in library card catalogs. On one side of this card is photographically copied on a greatly reduced scale (about 1:20) from fifty to one hundred pages of a book or magazine arranged in natural sequence. The smallness of the print necessitates, of course, that magnification be used for reading. In addition to the micro-copy of the book or magazine, the regular library catalog-card data relative to the text are shown in normal-sized print at the top of the card. This permits the text of a book or magazine to be filed and subsequently found with the ease associated with a card-index system. A sample microcard is shown in Figure 1; the fineness of the original print is inevitably lost in reproduction, but it will be seen that the card contains 98 pages.

The reader for microcards is illustrated in Figure 2. A greatly enlarged image of part of the card is projected on a nearly vertical ground-glass screen. The position of the image is controlled by adjustment of the central knob above the slot. Twisting the knob moves the image up or down the screen; sliding it sideways moves the image across the screen. One hand controls both movements. A second knob on the right-hand side of the device is for focusing. The card is very easily inserted into a holder which is exposed to view by merely raising the lid to which the central knob is attached (see Fig. 3). Reading can be done in a normally lit room but is somewhat easier in a room with subdued lighting.

Microcards clearly require only a minimum of space for storage and in this

* Manuscript received by the Editor, September 23, 1948.

† California Institute of Technology, Pasadena, California.

respect compete successfully with microfilm. They have a great advantage over microfilm in that they can be easily filed and stored in one operation and can be easily found when required. The smallness of the storage space provides a solution to a problem that is becoming acute for large libraries as a result of the rapidly increasing volume of published material. The fact that microcards can be easily found is extremely valuable in that a large part of the investigator's time is often at present absorbed in fruitless library hunting. The cost of microcards is lower than the cost of corresponding books. If the demand for them is as large as it should be, the cost will be very low indeed.

The most fundamental advantage of microcards is the possibility of their making more generally available the great deal of reference material at present

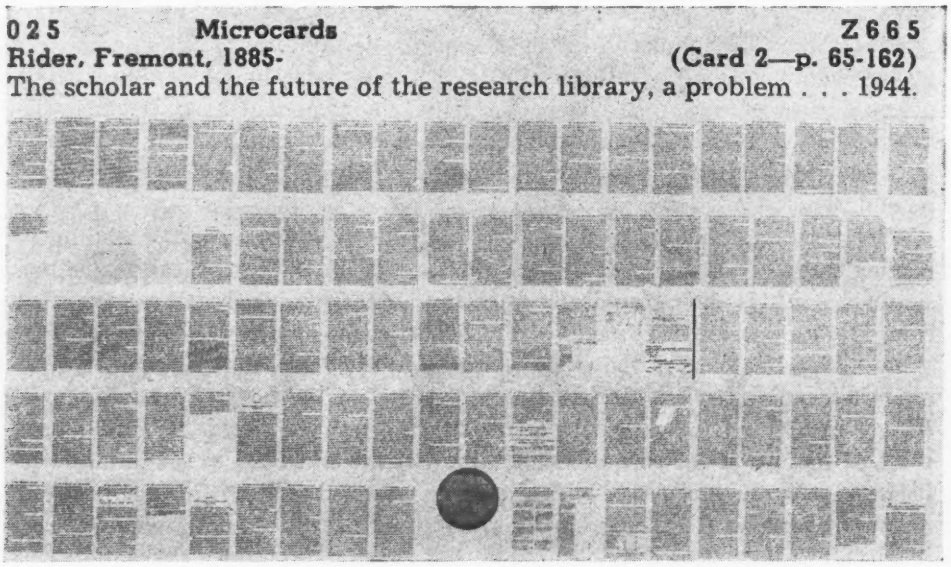

FIG. 1. Full-sized copy of a microcard. Observe that 98 book pages are included here on a single card. Library filing data, author, and title are given at the top.

contained in only a very few large libraries. This is of primary importance to any person engaged in engineering or scientific investigation. At present, even cities of more than 100,000 population rarely contain adequate technical reference libraries, and this deficiency is almost always passed on to the research project, resulting in work of inferior quality due to disregarding the pertinent work of other investigators.

Every college and university should have all available reference material on a subscription basis. Larger universities will probably find that microcard reference libraries may serve as departmental libraries, leaving the central library for the main collection of books. Every research organization should have complete ref-

erence material on subjects directly and indirectly related to its research projects; every town in the United States of over 50,000 should have a very complete reference library on microcards.

Individual investigators, also, will wish to strengthen their personal reference libraries, especially those whose work takes them to remote regions. A suitcase

FIG. 2. A microcard reader with image-positioning knob in center and focusing knob on right side.

full of carefully selected microcards and a reader would have been extremely valuable to the writer during a two-year residence in South America a few years ago.

Science and engineering are 100 percent human activities made possible by human intercommunication. We often refer to the accumulation of knowledge, meaning a social accumulation as well as an individual's. In no other field is the individual investigator more dependent on the social accumulation of knowledge than in the Sciences. It is not only wasteful of financial resources for an

investigator to ignore the work of others, but is wasteful of his own time and part of his useful life. If scientific investigations, viewed as social activities, are to be carried forward efficiently, reference libraries must be readily available. The *size* of the well-selected library sets a definite limit to the extent to which the investigator *can* make use of his predecessor's works. The easier the material is to find in a library, the more likely the investigator is to find it and profit by it.

These comments are of vital importance to present investigators, but for potential future scientists and engineers, the wide distribution of good reference

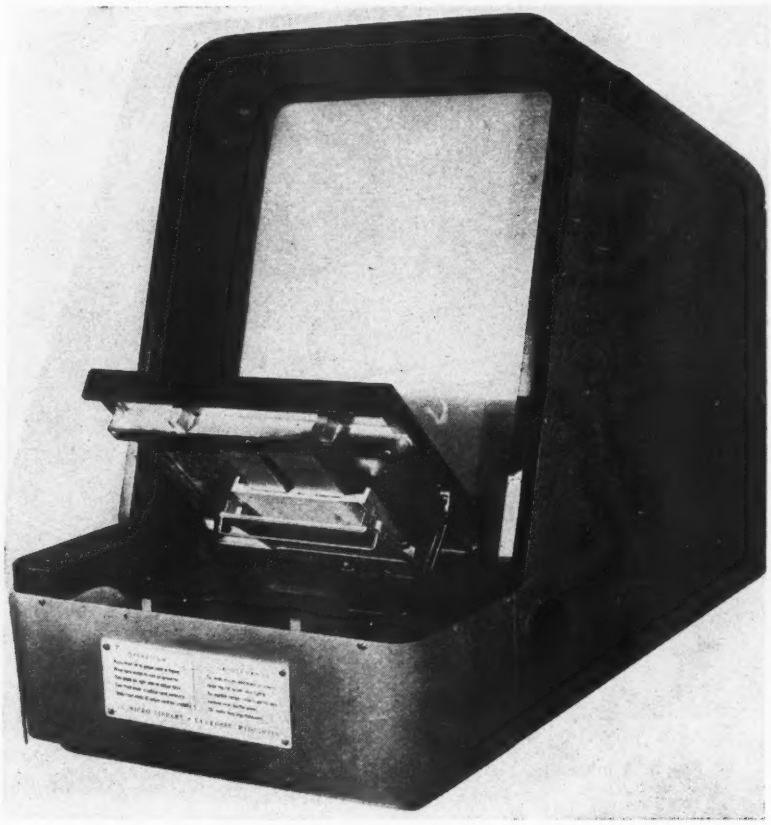

FIG. 3. The reader with lid raised for insertion of microcard.

libraries may help bring out the latent abilities of young people in more remote and isolated regions. The microcard, like every other tool of importance, derives its value from the fact that it helps to extend the power of the human organism to influence its environment. It appears probable that this new tool will prove to be extremely valuable.

Microcards were suggested by Fremont Rider in his book *The Scholar and the Future of the Research Library*.[1] Their development is in the hands of a co-operative committee of librarians, the Microcard Committee, Middletown, Connecticut, from which one may secure further information. The reader now available is made by The Micro Library, Inc., La Crosse, Wisconsin. The Microcard Foundation, a non-profit educational foundation, will initiate publication in six fields, namely Library Science, U. S. Government Documents, United Nations Publications, Mathematics, English Literature, and Geography. As an example, in Mathematics, Cauchy's *Oeuvres Completes* (Complete Works) 26 volumes in book form is selling at $180.00; when issued on microcards, the cost will be $22.70. Other companies are starting microcard publication in other fields.

As yet geologists, physicists, and geophysicists are not represented by any publisher of microcards.

[1] Fremont Rider, *The Scholar and the Future of the Research Library* (Hadham Press, 1944).

BARON ROLAND EÖTVÖS*

RAOUL VAJK†

Baron Roland Eötvös, inventor of the torsion balance, was born one hundred years ago, on July 27, 1848, in Budapest, Hungary. His father, Joseph Eötvös, was a prominent author and politician, who provided young Eötvös (the only son among his four children) with the best possible education. He graduated from high school in Budapest and became a student of law at the University of Budapest, as this was the suitable study for a young aristocrat in those days. However, Roland Eötvös had a strong inclination toward natural sciences and attended also lectures on astronomy, worked in the chemical laboratory of the university, and learned mathematics privately. Finally he turned entirely to physics and mathematics.

In 1867 Eötvös went to Heidelberg, Germany, where as a student of this famous university, he was closely associated with Professors Gustav Kirchoff, Robert Bunsen and Herman Helmholtz. In 1869 he attended a summer course at the University of Koenigsberg, Germany, where he learned potential theory from Franz Neumann and mathematics from F. Richelot. Returning to Heidelberg, he completed his studies and took his doctor degree in physics (major) and mathematics and chemistry (minors), with *summa cum laude.* In 1871 he became associate professor of mathematical physics at the University of Science, Budapest, and in 1872 he was appointed professor of theoretical physics at the same university. From 1876 he taught experimental physics also.

In 1876 Eötvös married the daughter of the Minister of Justice of Hungary and from this marriage he had two daughters.

Eötvös' work at the university as professor was interrupted for two years—in 1894, when he became a member of the Hungarian cabinet as Minister of Religion and Public Education, though he held this position only for about a half year. He was elected a member of the Royal Hungarian Academy of Sciences in 1883. The title of his inauguration address was "The Surface Tension of Liquids as a Function of the Absolute Temperature." He presented results of capillarity measurements on liquids proving the theoretical connection between surface energy and absolute temperature. He gave a method of determining the molecular weight from the change of surface tension due to temperature changes.

Eötvös' further scientific work was concentrated on the investigation of the earth's gravitational and magnetic fields. His paper, containing the results of eight years' work, was presented at the session of the Academy of Sciences on April 20, 1896. It gives a summary of his theoretical studies as well as the de-

* Manuscript received October 4, 1948.

† Standard Oil Co. Inc. New Jersey, 30 Rockefeller Plaza, New York, N. Y.

scription of his revolutionary new instruments for the study of the gravitational (and magnetic) potential fields.

In this classic paper Eötvös outlines the problem of measuring the variations of gravity in space; then he describes the method and the instruments which make possible the solution of the problem with an accuracy previously unbelievable. There is indeed hardly another example in the history of physics when a new, extremely accurate, sensitive instrument was made which is applicable not only for laboratory work but also for field observations, even by scientifically untrained observers. Theory and description of the horizontal variometer (curvature variometer), gravity variometer (commonly known as Eötvös torsion balance), magnetic translatometer, astatic magnetic variometer, gravitational compensator, gravitational multiplicator, and a new dynamical method for the determination of the gravitational constant is given in this single paper. The unusually rich content of this paper duly represents the ingenuity of a great scientist and his skill in experimentation.

I wish to call attention to one item in connection with the theory of the torsion balance. The determination of the gradient of gravity, that is, the rate of change of gravity in horizontal direction, would be a very difficult problem. However, as the gravity has a potential (U), the following equation exists:

$$\frac{\partial^2 U}{\partial x \partial z} = \frac{\partial^2 U}{\partial z \partial x};$$

that is,

$$\frac{\partial}{\partial x}\left(\frac{\partial U}{\partial z}\right) = \frac{\partial}{\partial z}\left(\frac{\partial U}{\partial x}\right).$$

It follows that the gradient of the gravity,

$$\frac{\partial}{\partial x}\left(\frac{\partial U}{\partial z}\right),$$

is equal to the rate of change of the x-component of the gravity in downward direction, which is

$$\frac{\partial}{\partial z}\left(\frac{\partial U}{\partial x}\right).$$

This is proportional to the curvature of the plumbline. By simply dropping one weight of the Coulomb torsion balance to a lower level, this magnitude, and consequently the gradient of gravity, can be accurately determined.

As the Eötvös torsion balance is principally a variation of the Coulomb torsion balance, which always has been an "enfant terrible" to the experimenting physicist because of its instability and of its capricious errors in readings, all these difficulties had to be overcome in order to create a reliable, steady instrument. Eötvös succeeded in solving these practical problems also by placing the balance in a small, properly designed, closed metal case with double (later triple)

walls. This secured an even temperature within the instrument, prohibiting the development of disturbing air currents. Another improvement was the replacement of the fragile quartz thread by heat-treated metal wire, of a diameter of 1/600 of an inch or less.

The experiments on the determination of the gravitational constant were made rather to test the new method than to reach high accuracy. Still, the preliminary value, $f = 6.65 \times 10^{-8} \pm 0.015 \times 10^{-8}$, is close to the now accepted best value, 6.664×10^{-8} cgs units.

With the aid of the principle of gravitational compensation, the high sensitivity of the Eötvös torsion balance may be increased even to the unstable, astatic state, making this instrument suitable for measuring extremely small gravitational effects. The gravitational multiplication serves the same purpose.

The magnetic translatometer is a little-known instrument. It is essentially a magnetic torsion balance. It is too sensitive for prospecting purposes and is suitable for measuring small magnetic effects. Eötvös determined the magnetic polarity of Etruscan vases and by this means determined "preserved" (it cannot be called "fossil") magnetism and the magnetic inclination of some thousand years ago (though the locality where these vases were baked was not known accurately). These experiments may be regarded as the forerunner of core orientation, as the magnetization of the baked clay is rather weak also.

Of the instruments described in Eötvös' above-mentioned paper, only the torsion balance was used in prospecting. It was an excellent tool in exploration for oil for about two decades, until it was replaced by the gravity meter.

Another principle which has a bearing on gravity surveys made at sea is the so-called Eötvös effect; that is, the weight of an eastward moving body is less, the weight of a westward moving body is more, than that of a body at rest on the earth's surface. Since 1905, all the gravity measurement made at sea are corrected for the velocity of the ship. The correctness of this principle was proven by experiments in May, 1908 by Professor Hecker, who made gravity measurements on the Black Sea travelling on the ship eastward and then westward at the same place. Eötvös himself designed an instrument to prove this effect in the laboratory. This consists of an ordinary balance beam with a weight at each end, which can be revolved around a vertical axis. If the number of revolutions per minute is equal to the period of the balance, the balance starts to swing as the weights on its two arms decrease and increase periodically, as they move to the east or west. This phenomenon was regarded as a proof for the revolution of the earth.

Due to the divergence of the equipotential surfaces of gravity toward the equator, the direction of the gravity force acting at the center of gravity of a floating body is different from the direction of the buoyancy force. The vectorial sum of these two forces is a horizontal force directed toward the equator. This results in a tendency of floating bodies (icebergs and continents) to drift toward the equator. By this theorem, Eötvös gave an explanation of the "*Pol Flucht*,"

or antipolar drift, which is suspected to create important orogenic forces causing the major deformation of the earth's crust.

Finally, it should be mentioned that Eötvös, with his associates D. Pekár and E. Fekete, worked out a method and proved experimentally with a high accuracy the proportionality of the inert and gravity masses, which is a basic assumption of the relativity theory.

Baron Roland Eötvös died on April 8, 1919, and left many unpublished manuscripts and scientific notes of his investigations. These are now, however, mostly obsolete as other researchers have attacked and solved the same problems. Baron Eötvös never had a patent on the torsion balance as he believed that the results of scientific researches should be for the benefit of all mankind. His investigations were financed by A. Semsey, who was one of the greatest Hungarian Maecenases of science, spending nearly 3,000,000 crowns ($600,000) for the advancement or various (mainly geological and geophysical) scientific developments and education.

WINTER OPERATION OF GEOPHYSICAL EQUIPMENT IN THE ROCKY MOUNTAIN AREA*

HARRY L. THOMSEN† AND GERALD A. BURTON‡

ABSTRACT

A large increase in geophysical activity in the Rocky Mountain Area has occurred during the last few years. In the past, most of the activity has been seasonal because of adverse weather conditions during the winter months. However, growing competition has resulted in a tendency for geophysical crews to carry on operations throughout the winter. The authors review the performance of several crews which have had experience in winter work, summarize problems connected with winter operations, and discuss methods which have been developed to improve efficiency under these conditions.

INTRODUCTION

It is the purpose of this paper to review the performance of geophysical crews which have operated during the winter months in the Rocky Mountain Region, and to discuss methods which have been developed to overcome problems arising from these winter operations.

In the past it had been anticipated that winter operation of geophysical equipment in this region of comparatively high altitudes and severe winter weather, might result in a prohibitive loss in efficiency. However, a review of the experience of a number of crews which have worked at least twelve consecutive months in Montana, Wyoming, Utah or northeastern Colorado, shows that, with proper winterizing of equipment and some latitude in selection of shooting areas, efficient year-round operations can be maintained.

REVIEW OF GEOPHYSICAL ACTIVITY

Activity in Crew Weeks Per Year.—Geophysical activity in the Rocky Mountain Region has increased in the past few years to a point where approximately 20 percent of all the crews operating in the United States now work in this area during the peak season.

Figure 1 illustrates the amount of geophysical activity in the Rocky Mountain Area in crew weeks of work per year during the period from 1942 through 1946. It can be seen that geophysical activity of all types jumped from 280 crew weeks in 1942 to more than 2,700 crew weeks in 1946—approximately a tenfold increase in four years. Seismic work has increased each year and has accounted for about 57 percent of all geophysical activity during these years. Gravity work, which accounted for approximately 40 percent of the total activity, increased each year through 1945, then showed a slight decrease between 1945 and 1946.

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† Shell Oil Co., Inc., Denver, Colorado.

‡ Shell Oil Co., Inc., Casper, Wyoming.

Magnetic work has amounted to approximately 3 percent of the total activity.

Activity in Number of Crews Per Month.—Figure 2 shows that the total amount of geophysical activity in this region has increased steadily during the past five years. These statistics show definite seasonal variation in the total number of crews. However, they also show that the number of crews remained essentially constant during the peak seasons of 1944, 1945, and 1946. Thus, the

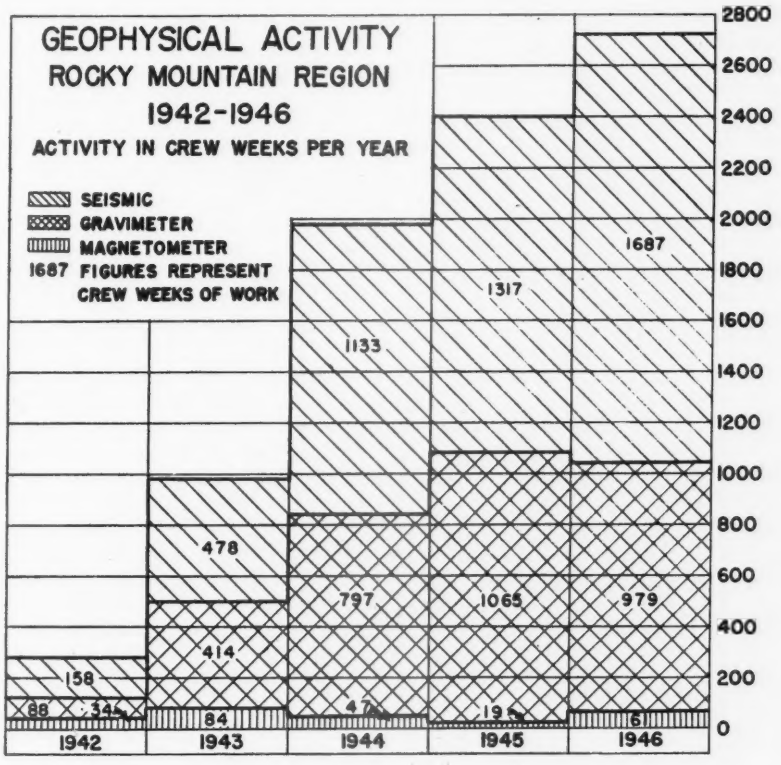

FIG. 1. Geophysical activity in crew weeks per year, Rocky Mountain Region, 1942–1946.

continued increase in the total amount of work done in the years 1945 and 1946 is due, not to a larger number of crews, but to a tendency for crews to continue working throughout the winter months. This is evident from the yearly increase in the number of crews working in the region during the period of minimum activity. This increase in winter activity has been more marked for seismic crews than for gravity or magnetometer crews.

Peak activity usually occurs in July, August, September, and October, whereas the minimum activity occurs in January, February and March. The most

popular working season appears to have been from May through November.

Seismic Production in Profiles Per Month.—In an attempt to analyze the effect of winter operation on the production of geophysical crews, statistics have been used for thirteen of the fifteen seismic crews which have worked at least twelve consecutive months in the area since 1943. Unfortunately, sufficient data were not available to warrant a similar analysis of seasonal variations in production for gravimeter or magnetometer crews.

The height of the columns in Figure 3 represents the average monthly production in profiles per month for the thirteen crews used in this analysis. The

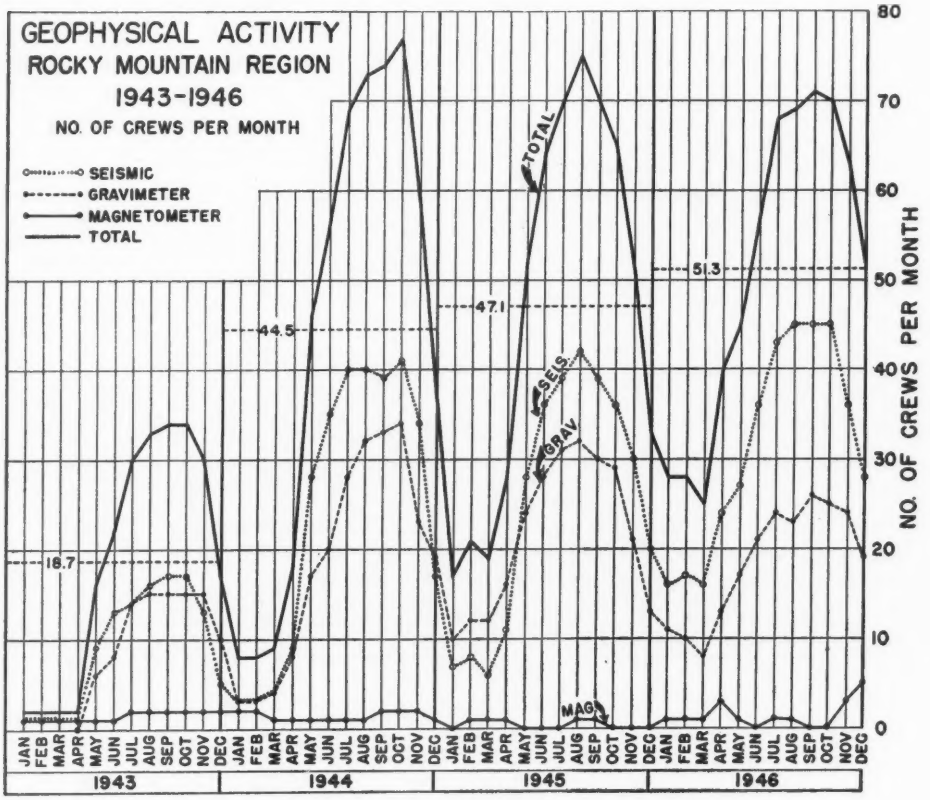

FIG. 2. Geophysical activity in number of crews per month, Rocky Mountain Region, 1943–1946.

blocks which make up each column represent various areas within the Rocky Mountain Region and the height of each block indicates the portion of the total production which can be ascribed to these areas. The black dashed curve represents the monthly average temperatures based on statistics from twenty-two

stations scattered throughout the areas in which these crews have worked.

It can be seen from Figure 3 that the yearly average number of profiles observed per crew per month is 92.0. Production is above this average for the months from March through August, and below this average from September through February. Although there may be a rough correlation between the average

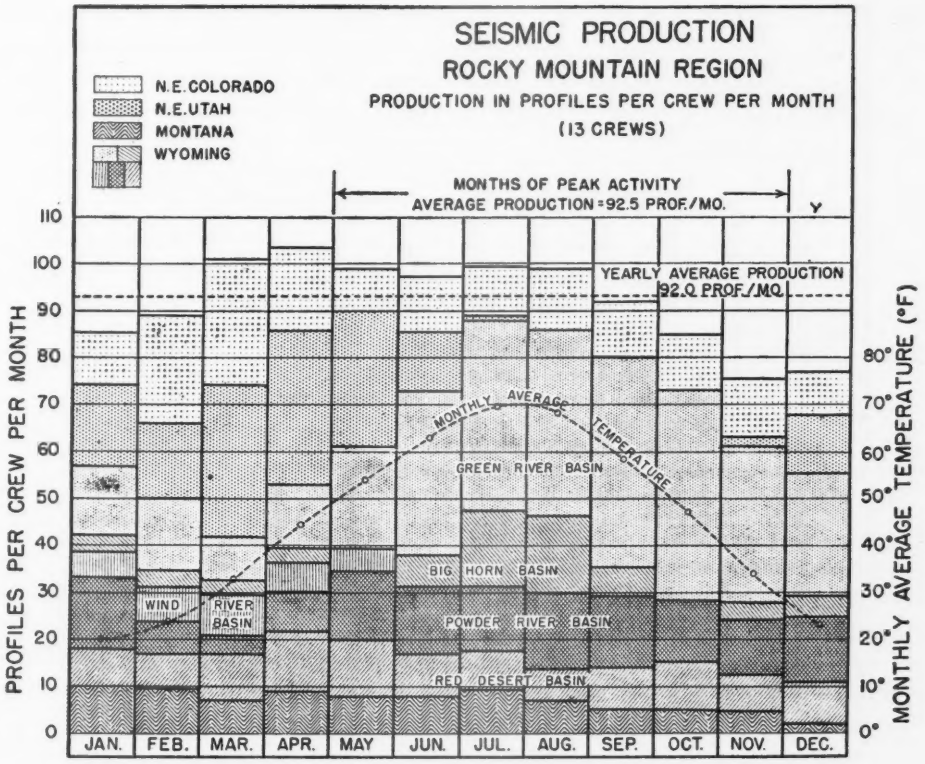

FIG. 3. Average Production in profiles per crew per month for 13 seismic crews which have operated in the Rocky Mountain Region for at least 12 consecutive months.

monthly production curve and the temperature curve, it appears that production may be affected more by shooting conditions in certain areas than by the temperature. For instance, production was high in March and April, when a large part of the total production came from northeastern Colorado and northeastern Utah. Furthermore, a decrease in the rate of production occurred in late summer and early fall when activity was high in the Green River Basin in southwestern Wyoming.

It is also of interest to note that the months of peak activity (May through November) do not coincide with the months of maximum production. The aver-

age production during the seven months of maximum geophysical activity is 92.5 profiles per crew per month. The average production from December through April (season of minimum activity) is 91.3, a decline of about 1 percent. Thus, on the basis of these statistics, a crew which worked during the seven months of peak activity could continue operating through the five months of minimum activity with no appreciable loss in production. Using a more pessimistic basis for analysis, it can be shown that if a crew which worked during the six months of best production, continued working through the six months of poor production, the average decline would be about 16 percent. This would amount to a loss of slightly less than one month's production at the rate realized during the months of best production.

OPERATION OF GEOPHYSICAL FIELD EQUIPMENT

The task of operating a geophysical field crew at maximum efficiency during the winter season is essentially one of preparation and maintenance. The principal problems fall into three general classifications:

1. General Automotive Equipment
2. Special Geophysical Equipment
3. Personnel

The discussion of these problems will center primarily around seismic operations, since it appears that the difficulties encountered in other geophysical methods are analogous.

General Automotive Equipment.—Experience has shown that, basically, most automotive equipment commonly used by geophysical crews is satisfactory for the winter shooting season. However, it is advisable that considerable winterizing be done if trouble-free operation is to be attained, especially if it is anticipated that the equipment may be left in the field overnight. By way of preparation, proper winter grade lubricants must be used, fuel and ignition systems must be kept free of ice and frost, and batteries must be kept at full charge to prevent freezing and to insure the starting of cold-stiffened motors. All cabs should be made weatherproof and reliable heaters installed. In addition, a close general maintenance check must be kept at all times, for experience has shown that if a mechanical weakness exists in a unit, it will certainly show up during the winter season.

Special Geophysical Equipment.—In regard to problems connected with winter operation of special geophysical equipment, those which apply to seismic drilling equipment are probably the most important. The main difficulty to be overcome in maintaining efficient drilling operations is the formation of ice in mud pumps. Although drain plugs may be installed which will allow almost complete draining of the mud end of the pump, there will usually be sufficient moisture left to allow freezing of the valves to the seats. Satisfactory solutions to this problem have been obtained by circulating the motor exhaust through jackets or coils around the pump or by direct circulation of the exhaust through the pump, kelly, foot valve, and flow lines.

Vacuum loaders and discharge lines on water trucks must also be winterized. Again, the most effective method of assuring trouble-free operation is the circulation of the motor exhaust around these parts. In some instances, crews have found the installation of a heater inside the water tanks to be helpful in combatting the formation of ice on tank baffles and walls. However, this is not essential, as efficient operation can be maintained if the water trucks can be placed in a heated storage occasionally, or thawed by use of a steam generator.

In the writers' opinion, one of the most useful pieces of supplementary drilling equipment is a properly constructed portable mud sump. The elimination of digging a sump in frozen ground usually reduces completion time on a shot hole by about one hour. Portable sumps with properly designed baffle systems have been found effective in what is considered to be the most difficult digging.

A piece of special equipment which has been found to be advantageous is a hot-air blower which keeps the rotary table, tongs, slips and control levers free from ice. The use of this feature reduces drilling time to some extent and adds greatly to the comfort and safety of drilling personnel.

Most standard seismic recording equipment appears to be only slightly affected by operating in sub-freezing temperatures. Some difficulty is occasionally encountered from the condensation of moisture or the formation of frost on amplifier chassis and optical systems. Although these are serious difficulties, they are usually remedied rather simply by operating the amplifiers continuously and by installing circulating fans to keep the air moving around the chassis and camera. In some instances, it has also been found necessary to install heating elements in camera housings to eliminate paper speed variations resulting from the congealing of lubricants in the camera motors.

Except for discomfort to personnel, only minor additional difficulties around the shotpoint are directly attributable to winter operations.

Most standard seismic explosives supplied in the Rocky Mountain Area contain sufficient antifreeze compounds to lower their freezing point below the lowest anticipated field temperature. As a result, ordinary field and truck magazines are satisfactory for all operations.

Personnel.—From a personnel standpoint, the objective to be considered in a winter campaign in the Rocky Mountain Region is the provision of a maximum amount of protection from severe weather conditions.

It has been found that, with proper clothing and equipment, productive operations can be carried on in temperatures as low as 15 to 20 degrees below zero, provided there is no wind. However, if the wind is blowing, work usually is inefficient when the temperature falls below zero. For working under extreme conditions, it has been found advisable, when possible, to use portable field heaters and wind screens to provide warmth and protection to the men in the field. This practice is effective in the case of drill crews, but too cumbersome for shooting or instrument crews.

From a safety point of view, it is advisable to take certain precautions and provide some emergency equipment to protect the field personnel in the event of

blizzards or breakdowns. If the work lies in sparsely populated regions, at least two men and two pieces of equipment should be kept together at all times. It is also important that the location of all units of the field party be known by personnel at the base of operations. Radio contact between the field and base of operations is, of course, valuable in this respect.

Finally, it is advisable to equip each automotive unit with sufficient emergency rations and equipment to sustain the men attached to the unit for a period long enough for a rescue party to reach them in the event of an emergency.

CONCLUSION

In conclusion, it may be said that it is the opinion of the writers that the ability of a geophysical field crew to maintain a high level of production during the winter season in the Rocky Mountain Region depends largely on (1) a flexible shooting program and schedule, (2) the proper preparation and maintenance of equipment and (3) the exercise of good judgment on the part of the supervisory and operating personnel.

ON THE MINIMUM OSCILLATORY CHARACTER OF SPHERICAL SEISMIC PULSES*

C. HEWITT DIX†

ABSTRACT

Compressional seismic pulses, such as originate from an explosion in a shot hole, can be discussed generally without reference to the non-linear effects, such as heating, fracturing and other departures from Hooke's law, in the neighborhood of the shot. A pulse of *finite* length from front to back is considered in the present note. It is shown that such a pulse is not as arbitrary as the general solution of the spherical wave equation would indicate, but the dilatation must change algebraic sign at least twice within the pulse. Thus the pulse must generally be, to this minimal extent, oscillatory if the front and rear regions are to be quiet.

INTRODUCTION

It is a well-known fact that seismograms of earthquakes and of disturbances caused by explosions show an oscillatory character. It has sometimes been considered that this oscillatory character must in some manner be accounted for in terms of departures from the simple spherical wave equation or in terms of the character of the source. Various researches have been conducted along these lines.[1,2,3,4]

While it must be admitted that this oscillatory characteristic of the pulses does arise at the source, none of the treatments appear quite satisfactory because of the neglect of what are probably major effects of non-linearity which arise near the source. Hooke's law is violated near the source. Temperature effects are probably important. Fractures occur.

It is the purpose of the present note to show that *any* spherical seismic pulse of finite length from front to back satisfying the spherical wave equation,

$$\frac{1}{r}\cdot\frac{\partial^2(r\cdot\Delta)}{\partial r^2}=\frac{1}{v^2}\frac{\partial^2\Delta}{\partial t^2}, \tag{1}$$

must have a certain minimum oscillatory character.

The usual outward-travelling pulse solution of equation (1) is

$$\Delta(r,t)=\Phi(r-vt)/r, \tag{2}$$

* California Institute of Technology, Division of the Geological Sciences, Contribution No. 470. Manuscript received by the Editor August 7, 1948.

† California Institute of Technology, Pasadena, California.

[1] H. Jeffreys, *Monthly Notices of the Royal Astron. Soc., Geophysical Supplement 2* (1931), 407–416.

[2] H. Kawasumi and R. Yosiyama, *Bull. Earthquake Res. Inst.*, Tokio Imp. Univ., *13* (1935), 496–503.

[3] J. A. Sharpe, *Geophysics*, VII, (1942), 144–154.

[4] C. Y. Fu, *Bull. of the Seis. Soc. of Amer., 35* (1945), 37–42.

where Φ is arbitrary excepting that it must be possible to differentiate $\Phi(\tau)$ twice with respect to τ in order to be able to verify that Δ is a solution of equation (1).

The above paragraph gives the usual statement of the situation. This statement needs to be further qualified if we suppose the interval from the front of the pulse to the back is finite *and* that in front of the pulse, the solid medium is quiet and in back of the back of the pulse, the medium is quiet. This we do suppose in the remainder of this note.

SOLUTION OF THE PROBLEM

Let the *phase* of the pulse be $\tau = r - vt$. Let τ_f and τ_b be the "front" (phase) and "back" (phase) respectively for $\Phi(\tau)$. Suppose that at $t=0$, $r_f = \tau_f$ and $r_b = \tau_b$ and $\tau_f > \tau_b > 0$ so that $r_f > r_b$. The "length of the pulse" is $\tau_f - \tau_b$. We are assuming that $\Phi(\tau) = 0$ for $-\infty \leqq \tau \leqq \tau_b$ and for $\tau_f \leqq \tau \leqq +\infty$. We shall not be interested in the times for which r must be negative to give a non-vanishing $\Phi(r - vt)$.

We also require that the radial component of displacement, $U(r, t)$, vanish except where $\Phi(r - vt)$ is non-vanishing; but Φ and U are related by

$$\Delta(r, t) = \frac{\partial U}{\partial r} + \frac{2}{r} \cdot U = \frac{\Phi(r - vt)}{r} . \tag{3}$$

We may easily verify by differentiation that equation (3) is equivalent to

$$r^2 \Delta(r, t) = r\Phi(r - vt) = \frac{\partial}{\partial r} \{r^2 \cdot U(r, t)\}. \tag{4}$$

Equation (4) may be integrated with respect to r from the front of the pulse to the back of the pulse, thus

$$r_{f,t} = \tau_f + vt$$

$$\int \frac{\partial}{\partial r} \{r^2 \cdot U(r, t)\} dr = r_{f,t}^2 \cdot U(r_{f,t}, t) - r_{b,t} \cdot U(r_{b,t}, t) = 0.$$

$$r_{b,t} = \tau_b + vt.$$

Hence

$$\int_{r_{b,t}}^{r_{f,t}} r\Phi(r - vt) dr = \int_{\tau_b}^{\tau_f} (\tau + vt)\Phi(\tau) d\tau = 0. \tag{5}$$

Since t is arbitrary, we must have both

$$\int_{\tau_b}^{\tau_f} \Phi(\tau) d\tau = 0 \tag{6}$$

and

$$\int_{\tau_b}^{\tau_f} \tau\Phi(\tau) d\tau = 0. \tag{7}$$

Relation to equation (6) is most easily pictured in terms of the statement "the area between the graph $\Phi=\Phi(\tau)$ and τ-axis is zero"—there must be as much negative area (graph below the τ-axis) as positive area (graph above the τ-axis). This requires that the graph of $\Phi(\tau)$ cross the τ-axis *at least once* between τ_f and τ_b.

But one crossing will not satisfy both equations (6) and (7). Imagine now that $\Phi(\tau)$ represents pressure or normal force per unit length on the τ-axis. Then equation (6) says the upward force is equal to the downward force; but equation (7) says the moment of the upward force is equal and opposite to the moment of the downward force. Since equation (6) says the forces are equal and evidently the lever arms are not equal, the moments cannot be equal, *if* only two forces are involved. There must be *at least three* forces with alternating signs to satisfy both conditions of equations (6) and (7).

Two intermediate zero points representing places where the graph of $\Phi(\tau)$ crosses the τ-axis will satisfy both equations (6) and (7). This is easily seen since if τ_1 and τ_2 are such that $\tau_b<\tau_1<\tau_2<\tau_f$ and $\Phi(\tau_1)=\Phi(\tau_2)=0$, then equation (6) may be rewritten

$$A + B + C = 0, \tag{8}$$

where

$$A = \int_{\tau_b}^{\tau_1} \Phi(\tau)d\tau,$$

$$B = \int_{\tau_1}^{\tau_2} \Phi(\tau)d\tau,$$

and

$$C = \int_{\tau_2}^{\tau_f} \Phi(\tau)d\tau.$$

Also equation (7) can be rewritten

$$\bar{\tau}_1 \cdot A + \bar{\tau}_2 \cdot B + \bar{\tau}_3 \cdot C = 0 \tag{9}$$

where

$$\bar{\tau}_1 = \int_{\tau_b}^{\tau_1} \tau\Phi(\tau)d\tau/A,$$

$$\bar{\tau}_2 = \int_{\tau_1}^{\tau_2} \tau\Phi(\tau)d\tau/B,$$

and

$$\bar{\tau}_3 = \int_{\tau_2}^{\tau_f} \tau\Phi(\tau)d\tau/C.$$

One may first select $\Phi(\tau)$ between τ_2 and τ_f arbitrarily, except for the derivative requirements and the requirement that $\Phi(\tau_2)=\Phi(\tau_f)=0$, and the requirement that $C\neq 0$. Then $\bar{\tau}_3$ is computed and the product $\bar{\tau}_3$, C is formed. Then $\bar{\tau}_2$ and $\bar{\tau}_1$ can be arbitrarily selected subject to $\tau_b<\bar{\tau}_1<\tau_2$ and $\tau_1<\bar{\tau}_2<\tau_f$. Then A and B are computed. Since many forms of $\Phi(\tau)$ will satisfy both equations (6) and (7) or (8) and (9), $\Phi(\tau)$ still has a great deal of flexibility with respect to possible forms.

However this degree of flexibility is restricted as $\Phi(\tau)$ *must cross the* τ*-axis twice, at least, between the front and back of the pulse.* Thus in all practical cases where energy is supplied only for a limited time interval, a spherical seismic pulse of the compressional type must have a minimal oscillatory character—the dilatation must show 1.5 oscillations at least.

The radial displacement, U, may easily be computed by integrating equation (4); thus

$$U(r, t) = \frac{1}{r^2}\int_{r_{b,t}=\tau_b+vt}^{r} r\Phi(r - vt)dr. \tag{10}$$

The value of $U(r, t)$ is thus computable from equation (10) when $\Phi(\tau)$ is given in each particular case. Generally $U(r, t)$ crosses the axis only once when Φ crosses it twice between front and back.

CONCLUDING REMARKS

The above restrictions on $\Delta(r, t)$ (the dilatation) and on $U(r, t)$ (the radial displacement) are general restrictions. They must apply to any real case. In such a case the source energy builds up beginning at a certain time, t_0, and is all carried outwards so that the neighborhood of the source is, and remains, a region of zero energy after a finite time interval t_1-t_0.

Treatments based on a consideration of the source have assumed the process isothermal near the source and that all dynamical relations expressed by the simple linear Hooke's law hold. Failure of both of these hypotheses near the source is almost certain. Conclusions based on these doubtful hypotheses are, of course, doubtful. The present study, being based on reliable hypotheses, appears to reach similar conclusions, which are now more reliable.

STUDIES IN FAULT DETECTION WITH THE REFLECTION SEISMOGRAPH*

MARTIN C. KELSEY†

ABSTRACT

Faulting has long been recognized as an important factor in the formation of traps for the accumulation of oil and gas. A discussion is presented of some of the problems connected with fault interpretation, together with suggestions as to methods which may be employed to assist in the solution. Field data and final fault interpretation of a peculiar problem are herein illustrated.

INTRODUCTION

The importance of the role faulting plays in producing structural traps suitable for the accumulation of oil and gas has long been recognized. The difficulties of accurately mapping fault complications associated with structure are variable from area to area, being directly influenced by a combination of surface and subsurface conditions.

Take, for instance, an area of dominant, persistent reflected energy. Where favorable surface conditions allow the selection of well-planned lines of control, the interpretation of faulting is usually relatively simple. On the other hand, should adverse surface conditions such as (1) rugged topography, (2) heavily wooded terrain, (3) old drainage channels, or (4) large unpermitted tracts of land lead to the necessity of crooked lines of control, the problem of fault detection becomes increasingly difficult.

DEFINITIONS

Although it is not the purpose of this paper to delve at length into the terms and definitions of all the various types of faulting, perhaps it is well that we refer to the block diagram shown in Figure 1. Here, $MNOP$ is the fault plane of a normal fault. In the vertical plane BAC, normal to the strike of the fault, the angle BAC, or β, is the dip angle of the fault zone. In another vertical plane varying from normal to the strike of the fault, the angle $B'AC'$, or α, is the apparent dip of the fault in that plane. Given the true dip of a fault, β, and the horizontal plane angle, θ, between the vertical plane of true dip and the vertical plane of apparent dip, the apparent dip, α, of a fault trace may be computed from the following equation:

$$\tan \alpha = \tan \beta \cdot \cos \theta.$$

In this we observe that the apparent dip of a fault zone may vary from 0°, when the line of control is parallel to the fault trace, to the true dip of the fault, when the line crosses normal to the strike of the fault.

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FAULT-TRACE PATTERN ON CROOKED-LINE VERSUS STRAIGHT-LINE CONTROL

In order to study some of the interpretation difficulties introduced by the use of crooked control lines across a fault trace, attention is called to the hypothetical map shown in Figure 2. Here a fault trace is shown trending northwest-southeast. Note the position of the control obtained along line 1 as the line swings back and forth across the fault trace. Attention is invited to the cross section of the control obtained along line 1 as shown in Figure 3. Beginning at the east end of the line of control, where five well-spaced reflecting horizons are indicated as beds *A* through *E*, and progressing westward to shotpoint 4, one will observe that a

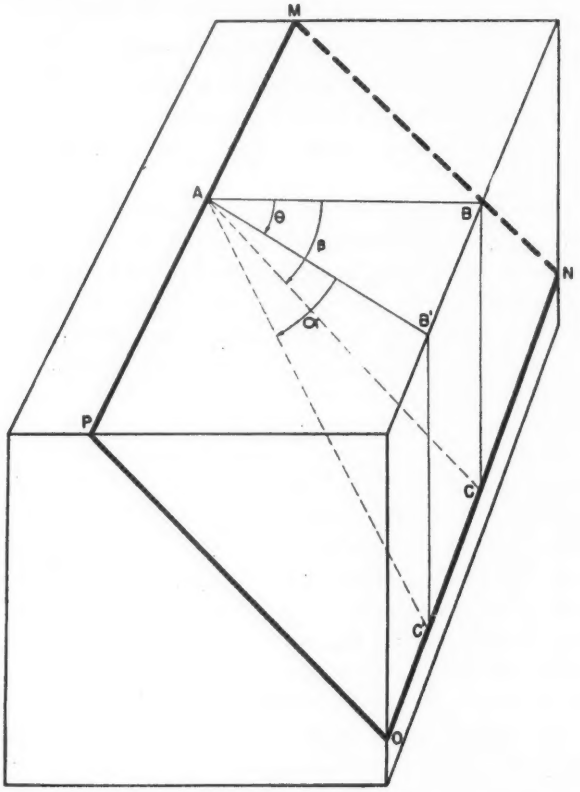

FIG. 1. Block diagram showing relation of fault trace, dip, and apparent dip.

fault zone has been indicated as downthrown to the west. In the zone between shotpoints 2, 3, and 4, note that the displacement shown on beds *A*, *B*, and *C* is some 600 feet. The first segment of control lies in a straight line and the interpretation is relatively simple. However, due to the change in bearing of the control line at shotpoint 4, note the position of the fault trace in the zone between

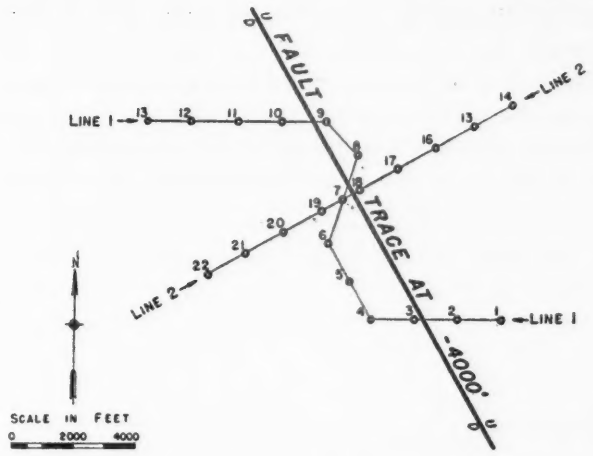

FIG. 2. Map showing location of control lines across a faulted area.

shotpoints 4 and 6 where the line of control is parallel to the fault trace.

At shotpoint 6 the bearing of the control line changes again, swinging back to the northeast. Note the position and apparent dip of the fault trace in the zone between shotpoints 6 and 8 where beds *C* and *D* are again observed on the upthrown side of the fault.

Another bearing change in the line is indicated at shotpoint 8. Here, where the line of control is approximately parallel to the fault trace between shotpoints 8 and 9, one will observe the apparent dip and position of the fault trace.

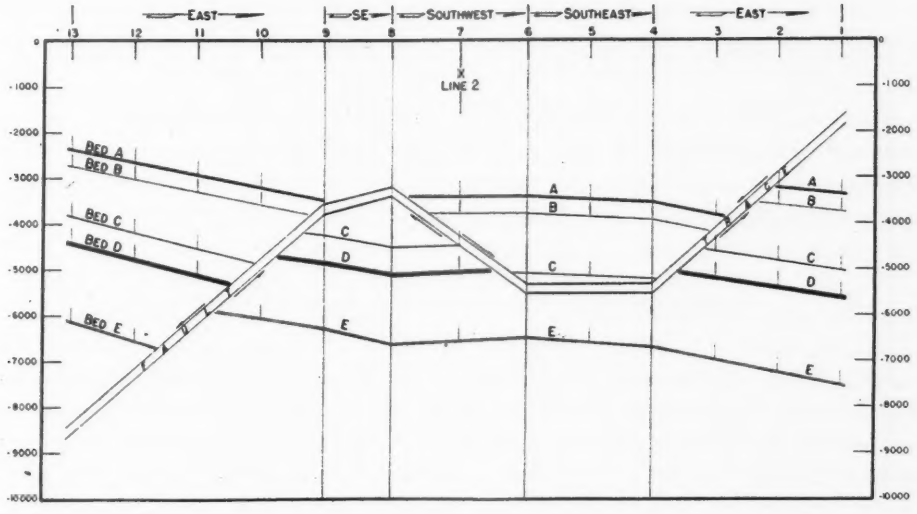

FIG. 3. Cross-section data obtained on Line 1, a crooked line of control across a fault zone.

The bearing of the line swings to the west at shotpoint 9. In the zone between shotpoints 9 and 13, the fault observation is straightforward and for the first time the control on bed *E* has been observed to cross the fault trace.

In order to compare the fault-interpretation difficulty on crooked and straight lines of control, let us refer to the map showing the location of the control points and the position of the fault trace as shown in Figure 2. Note the position of the

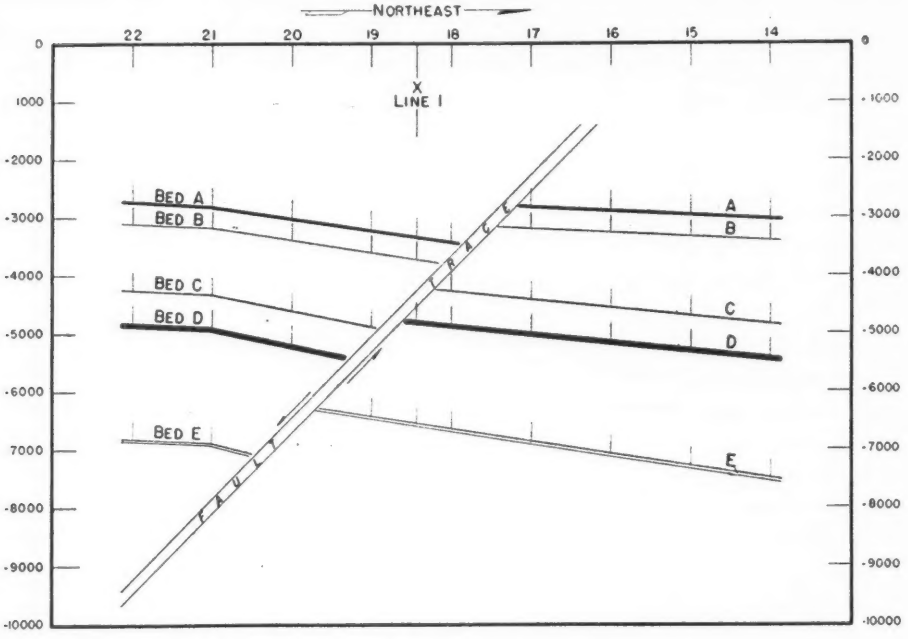

FIG. 4. Cross-section data obtained on Line 2, a straight line of control across a fault zone.

control obtained on line 2 and the fact that this line crosses the fault normal to the fault trace. Attention is now invited to the cross section of control obtained on line 2 as shown in Figure 4. It is evident that the fault-interpretation difficulties have been reduced to a minimum on this line of control by purposely locating the line to cross the fault in a plane normal to the fault trace.

A METHOD OF PLANNING CONTROL LINES IN FAULT-COMPLICATED AREAS

When the true-dip angle of faults is known in an area, it is often possible to predict a fault bearing in the careful study of data obtained on a single line of control. In the effort to conduct a survey by means of well-planned control lines in faulted areas, careful study of the record and cross-section evidence of faulting often permits a valid determination of the apparent dip of a fault. Attention is invited to the family of curves shown in Figure 5. Here the apparent dip angle of

faults, with variable true dips, are shown as a function of the horizontal plane angle θ between the fault-trace bearing and the line of control. Although this chart does not allow a unique solution since two alternative fault bearings are

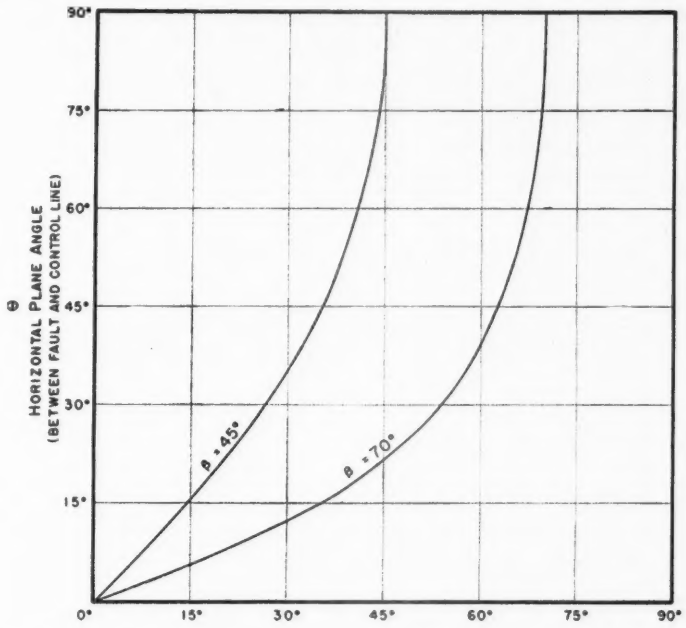

FIG. 5. Family of curves showing the apparent dip of faults versus the horizontal plane angle between the fault bearing and the line of control.

possible, its use has proven worth-while in planning lines of control in fault-complicated areas.

SUBMERGED FAULTS

In working within the limitations presented by the use of two-dimensional cross-section paper, we must ever be aware of the fact that we are dealing with a three-dimensional problem in all structural interpretation. Continual realization of this problem is particularly necessary in fault-complicated areas, where extreme variations in dip direction and magnitude often occur abruptly.

In the effort to attain accurate structural interpretation, the geophysicist must become familiar with the geologic section he is working. He should learn all that is known about the position or positions of unconformities in the section. Finally, he must remain aware of the physical laws which govern the recording of the reflected energy with which he works daily.

In Figure 6 attention is invited to a suite of three alternate recordings across a submerged fault zone. Note that the three reflected events above the unconformity, indicated in the depth zone of arrivals between 1.3 and 1.4 seconds, are

continuous and show no signs of fault displacement. Below the unconformity faulting has been interpreted. On the center record, note the differential dip indicated on the event arrivals between 1.6 and 1.8 seconds. Obviously the depth points of the upper or shallower event, showing rather steep west dip, were re-

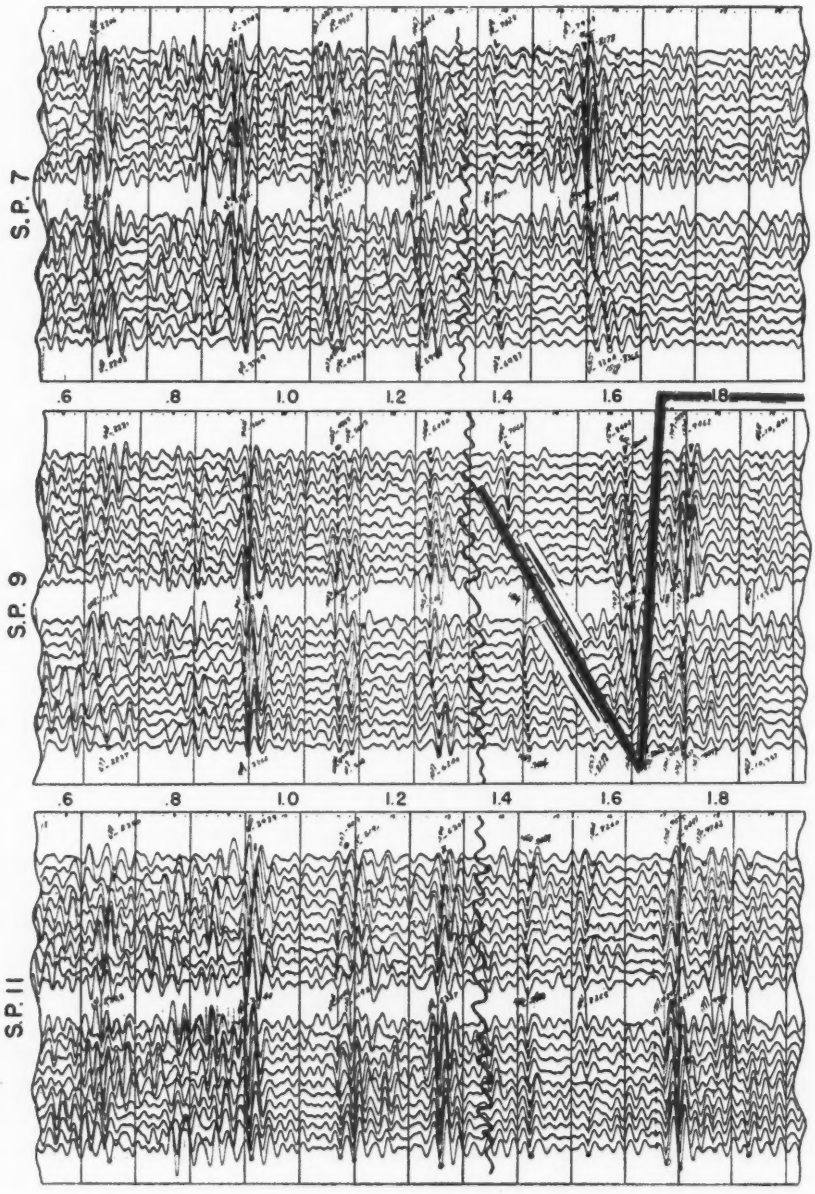

FIG. 6. A suite of three alternate recordings across a submerged fault zone.

corded from the zone to the east of the surface set-up position. The "cross-spread" recording obtained from the shotpoint, also utilized in recording the center-record line profile, further reveals the differential attitude of the two reflecting surfaces. In this particular case the two bands of reflected energy recorded between 1.6 and 1.8 seconds are interpreted as reflections from the same horizon on opposite sides of a fault zone. Attention is called to the pattern of the fault trace across the center record.

The local structural pattern of the faulted horizon is shown in Figure 7. Here, by means of resultant dip determinations, the depth-point positions have been

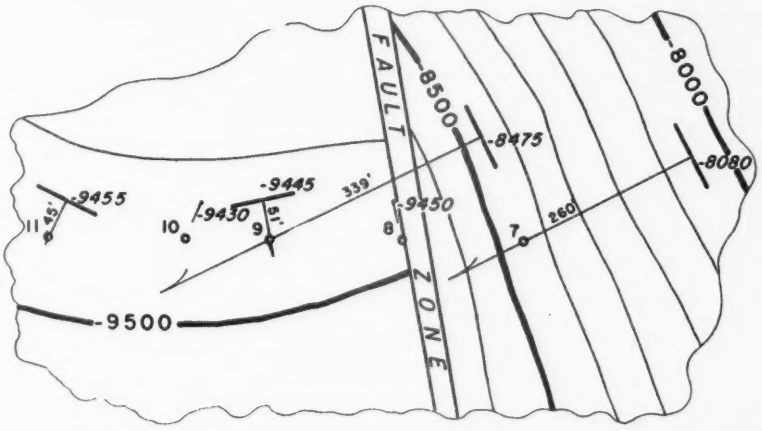

FIG. 7. Structural interpretation of the data shown in Figure 6.

determined and the corresponding corrected depths computed. Note that the data do not overlap when the depth-point placement is taken into consideration.

CONCLUSIONS

In these studies we have observed that the evidence of faulting is not always clear-cut in areas of strong, persistent reflected energy. In areas of weak reflectors the evidence of faulting is usually more obscure, even in zones where the surface conditions are favorable.

In the detection of faulting with the reflection seismograph, no panacea or cure-all method has been revealed. In lieu of such a method it is suggested that we can best cope with the problem of accurate structural interpretation by carefully planning the position of control lines in fault-complicated areas. In a careful study of the records and cross sections, we must always be aware of the three-dimensional problem involved in the structural interpretation. In this connection it is essential that the survey program include ample control for the determination of true or resultant dip stations as required for the proper placement of the depth points.

ACKNOWLEDGMENTS

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SEISMOGRAPH DETERMINATION OF SALT-DOME BOUNDARY USING WELL DETECTOR DEEP ON DOME FLANK*

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ABSTRACT

A method is given for determining the boundary of a salt dome, based upon first-arrival time measurements of seismic waves from ordinary shotpoints distributed around the dome and received by a well detector within a deep hole flanking the dome. The three-dimensional problem of locating the dome boundary, taking account of radial and vertical changes of velocity within the surrounding sedimentary section, is solved by the determination of vertical and horizontal cross sections of "aplanatic surfaces" as set forth. A practical procedure for such a survey is briefly outlined.

INTRODUCTION

The method of using a well detector deep in a drilled hole, near or within a salt dome, receiving seismic waves from shotpoints distributed on the ground surface in the general area of the dome for the purpose of determining the dome boundary, was first described by McCollum and La Rue.[1] The three-dimensional problem, which is presented by the case of the detector being located deep on the flank of a dome, is one which has not been treated in the literature. This case is particularly interesting for two reasons: First, deep tests which are drilled on the flanks of domes occasionally provide an open hole for carrying out such a survey; and second, the same hole can be used effectively and economically for obtaining information on velocities within the surrounding geologic section. This information is essential to the success of the method, which depends fundamentally upon the contrast of velocities within salt and the surrounding geologic section.

In attacking this problem, the primary question immediately arises: Given the locations of a shotpoint and detector, known to be in two different media having known velocities, and the minimum (or first-arrival) travel time of a wave between the shotpoint and detector, what information can be obtained as to the interface between the two media? Referring to Figure 1, an "aplanatic"‡ or limiting surface can be constructed which satisfies the condition that the sum of the travel times in the two media shall equal the given total travel time T. This surface will always be convex toward the high-velocity medium. If the two media have uniform velocities, it will be a surface of revolution about the axis SD.

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† Gulf Research and Development Company.

[1] Burton McCollum and Wilton W. LaRue, "Utilization of Existing Wells in Seismograph Work," *Bull. AAPG, 15* (Dec., 1931), 1409.

‡ Dr. C. A. Swartz used "aplanatic surfaces" in analyzing a two-dimensional hypothetical salt-dome problem in 1934. The present method was first used in 1937.

Now, it can be recognized that an interface tangent to the three-dimensional aplanatic surface at any point thereon satisfies the primary question. The problem of finding the dome boundary devolves into one of representing and synthesizing aplanatic surfaces. Figure 2 illustrates in perspective an aplanatic surface tangent to a salt dome. If several neighboring aplanatic surfaces are determined in space by the use of a corresponding number of spaced shotpoints, the dome boundary must be tangent to them all, and thus, its position is closely constrained.

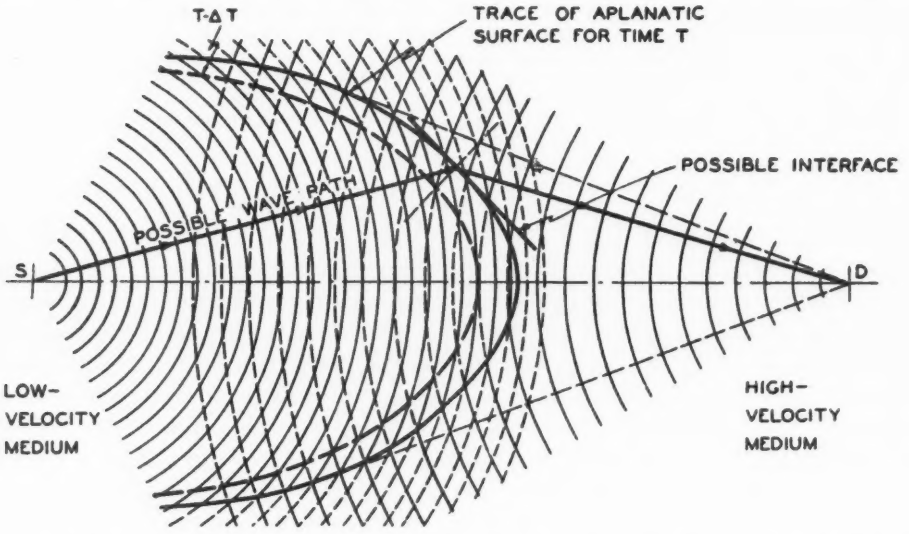

FIG. 1. Two-dimensional construction of trace of aplanatic surface for the case of two different uniform media, and possible position of interface tangent thereto.

An areal distribution of shotpoints around the dome will fix aplanatic surfaces surrounding the dome and thereby locate its boundary. A limitation to be borne in mind is that any very sharp recesses in the boundary of the dome will tend to be masked or smoothed out in results, since the aplanatic surfaces will touch neighboring points on the dome surface in preference to the recesses.

The simple two-dimensional construction of Figure 1 is readily accomplished graphically by the use of diverging wave fronts from the shotpoint, and converging wave fronts toward the detector, representing travel times within two uniform media. Intersections of particular wave fronts, which satisfy the condition that the total time shall equal the given time, fix the trace of the associated aplanatic surface. If a smaller travel time, say T-ΔT, is given, the position of the aplanatic surface will be shifted toward the low-velocity medium, and the interface will be determined at a correspondingly shifted position. A condition which the given travel time must satisfy is that it must be intermediate between the times required to traverse the distance SD at the low and high velocities.

For a shallow salt dome, a fairly direct and quite accurate measure of the velocity of salt can be obtained from a recording of seismic-wave travel time from a shotpoint *V* (over the top of the dome), Figure 2. The depth of a refraction point on top of the dome and the travel time to this refraction point, may be determined from surface refraction shooting on the top of the dome as a marker

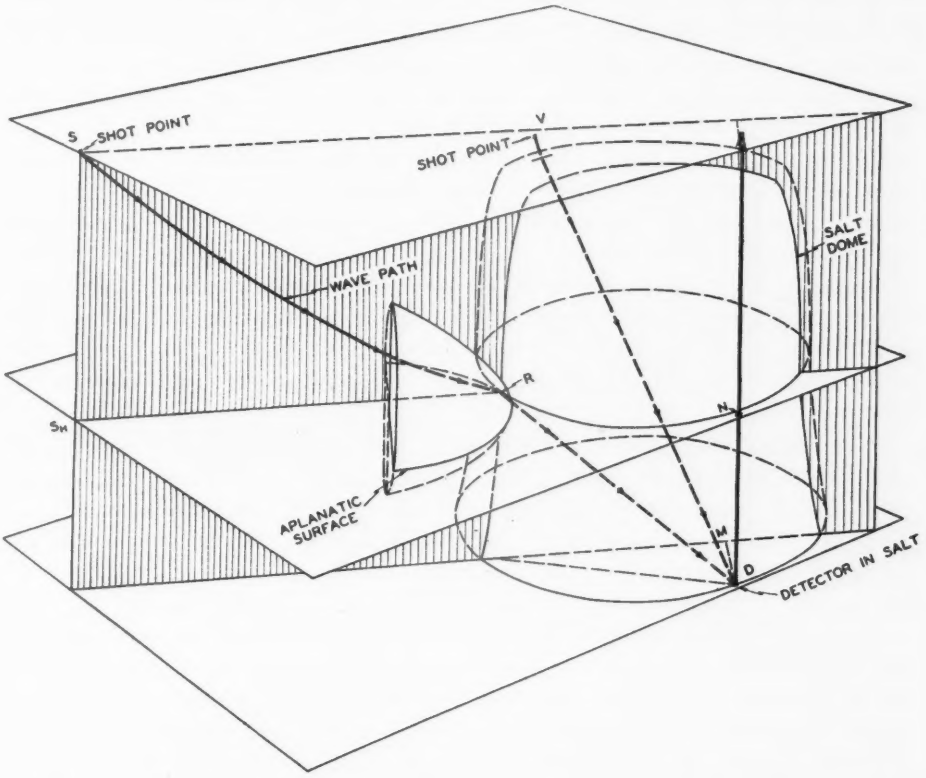

FIG. 2. Perspective view of salt dome with well detector located deep on its flank in an open hole An aplanatic surface, associated with seismic wave path *SRD*, tangent to the dome is illustrated; also sample vertical and horizontal planes cutting the aplanatic surface. Wave path *VD* is used for determining the seismic wave velocity within the dome.

horizon. Having accounted for these factors, the path length and associated travel time from the refraction point to the detector become determined, and hence the average velocity within the dome is measured.

The velocity of salt throughout the dome is assumed to be constant and equal to this measured value. More than one such determination may be made and results averaged. In some cases, it may be known or found from surface refraction shooting over it, that the dome has a cap-rock cover which is characterized by a velocity appreciably higher than that of salt. In such a case, a velocity for salt

slightly too high would be determined by this method. Allowance for this influence may be made, but usually it will be negligible.

After the velocity of salt has been determined for a few sample domes, a fairly good value is established for general use. Such a value is 15,000 ft/sec. Still further control on the velocity within the dome is afforded by comparison of the results of analysis of a radial survey of a dome with point locations on the dome boundary as established by any existing well surveys. Discrepancies found from such a comparison may call for some modification of the assigned salt velocity and consequent adjustment of results. Fairly good values for salt velocity can be obtained from these considerations alone.

In general, the velocity within the geologic section surrounding the dome increases with depth and also may vary laterally. Wave paths within such a medium generally are curves, concave upward. A refraction point *R*, associated with any given curved wave path *SRD* (Fig. 2), ordinarily is deeper on the flank of the dome than would be the case if the wave paths were straight. Consequently, the existing velocity distribution around any particular dome influences the depth at which control on the dome flank can be obtained. A high-velocity marker in the section tends to prevent attainment of control on the dome flanks below its level.

The desired information on the velocity distribution within the surrounding section can be obtained by considerably expanding an ordinary well velocity survey in the deep hole. Recordings are made of wave travel times to the well detector at a multiplicity of depth levels from a series of spaced shotpoints along a profile which extends from the deep test hole in a direction away from the dome. From these data a "wave-front chart" is constructed, as shown in Figure 3.

Horizontal components of distance from shot to detector are represented as abscissae, vertical components as ordinates. With these coordinates, observed travel times for the various depths and distances are recorded. Smooth "wave fronts" then are constructed to fit these data. A precaution to be observed is to avoid the use of time data from trajectories refracted along salt. This chart implicitly incorporates lateral and vertical variations in velocity in a manner that is appropriate for the use of the chart in finding the dome boundary. It does not give a true representation of wave fronts emanating from any fixed shotpoint. The velocity distribution within the section surrounding the dome is assumed to be represented by this chart along any profile extending radially or nearly radially away from the dome in any direction. However, modifying adjustments may be applied to take account, for instance, of regional velocity change or to satisfy known control points on the dome boundary.

Figure 3 also illustrates how the trace of an aplanatic surface in a vertical plane containing a shotpoint and the well detector at depth within salt is found. A linear scale is constructed which expresses travel time at the salt velocity for any given distance. This scale is pivoted at the position of the well detector, which must be properly located in relation to the shotpoint position taken at the origin

of the wave-front chart. The scale then is rotated about its pivot to locate a set of points which satisfy the condition that the sum of a time represented on the wave-front chart and a time on the scale shall equal the observed travel time (exemplified for a travel time of 1.84 seconds). A curve connecting these points is the trace of the aplanatic surface in the vertical plane.

To construct the trace of an aplanatic surface in any chosen vertical plane containing a shotpoint but not the detector, it is convenient to represent the

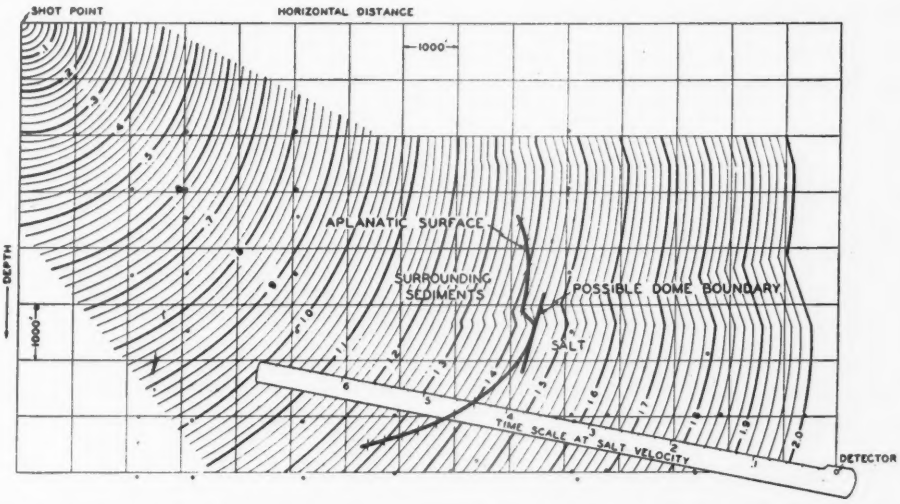

FIG. 3. Wave-front chart for geologic section surrounding salt dome, and two-dimensional construction of aplanatic surface in vertical plane, satisfying travel time of 1.84 seconds.

chosen vertical plane by a sheet of transparent paper laid flat on a table top as shown in Figure 4. The detector position then is at a height *DM* perpendicularly above the plane, cf. Figure 2. The construction of the trace now is performed in the same manner as for the case described above (with the detector in the plane). The wave-front chart is placed in proper position under the transparent construc-

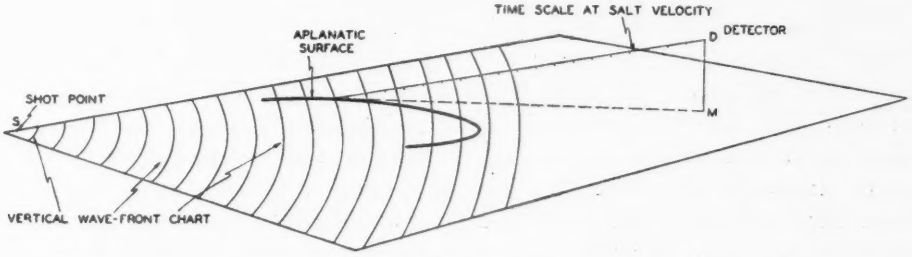

FIG. 4. Construction layout to determine trace of aplanatic surface in any chosen vertical plane containing shot but not detector. Vertical plane is represented as laid flat on a table top.

tion paper. However, in this case, the linear time scale at salt velocity has its pivot point supported at point D above the table. This scale must be flexible (paper is suitable) and held taut between its pivot and the trace of the aplanatic surface being constructed. The edge of the scale, in this position, is representative of a possible wave travel path in the salt dome, depending upon the condition of tangency of the aplanatic surface to the dome boundary.

Traces of aplanatic surfaces in any chosen horizontal plane may also be determined, for example, in the central horizontal plane depicted in Figure 2. Figure 5 illustrates the construction layout on a table top, which conforms with the illustration of Figure 2, except that in Figure 5, the line ND is projected perpendicularly upward instead of downward. Travel time within the geologic sec-

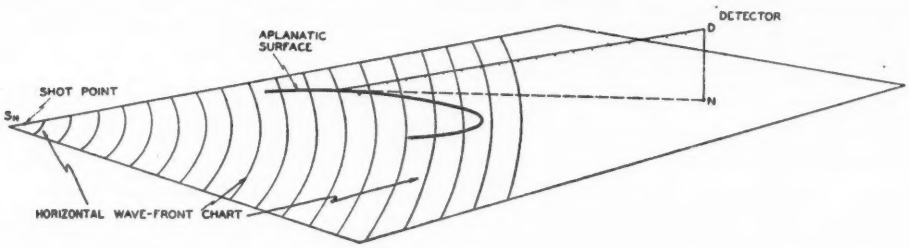

FIG. 5. Construction layout to determine trace of aplanatic surface in any chosen horizontal plane. Line ND of Figure 2 is projected perpendicularly upward instead of downward.

tion to any point in the chosen horizontal plane is represented by a specially constructed "horizontal" wave-front chart. The vertical wave-front chart (Figure 3) is simply a vertical cross section of the spatial wave fronts, which are surfaces of revolution about a vertical line through the shotpoint, and the horizontal wave-front chart is a horizontal cross section. Accordingly, the horizontal wave-front chart consists of arcs of circles, centered at the shotpoint projection S_H, having radii and corresponding time value taken from the vertical wave-front chart at the level of the horizontal plane. Using this wave-front chart in the layout of Figure 5, with the position D as illustrated being the pivot point for the salt time scale, the horizontal trace of the aplanatic surface is constructed in the same manner as described above for a vertical plane.

A suitable arrangement of shotpoints for determining the boundary of a salt dome is illustrated in Figure 6. Usually the position of the dome is roughly known from other information. However, if not, it can be roughly determined from a few scattered shots by the present method. The directions of the profiles are set in alignment with estimated horizontal components of wave paths, which are refracted at the dome boundary and converge toward the detector position. Under this condition, waves from all shotpoints on any given profile will yield control points on the dome boundary approximately in a vertical plane containing the profile. Accordingly, traces of a set of aplanatic surfaces, constructed in this vertical plane, will determine a vertical section of the dome boundary to a first

approximation. Another property of this arrangement of shotpoints is that it yields a fairly regular distribution of control points on the dome boundary. However, this arrangement is not a requirement.

Figure 7 illustrates traces of aplanatic surfaces and an associated approximate trace or section of the dome boundary in a vertical plane containing a profile of shotpoints. From a complete set of such sections, constructed for all profiles, a contour map of the approximate dome boundary can be constructed.

The accuracy of the approximation depends upon how nearly the vertical traces of aplanatic surfaces, constructed as described, are in correct horizontal

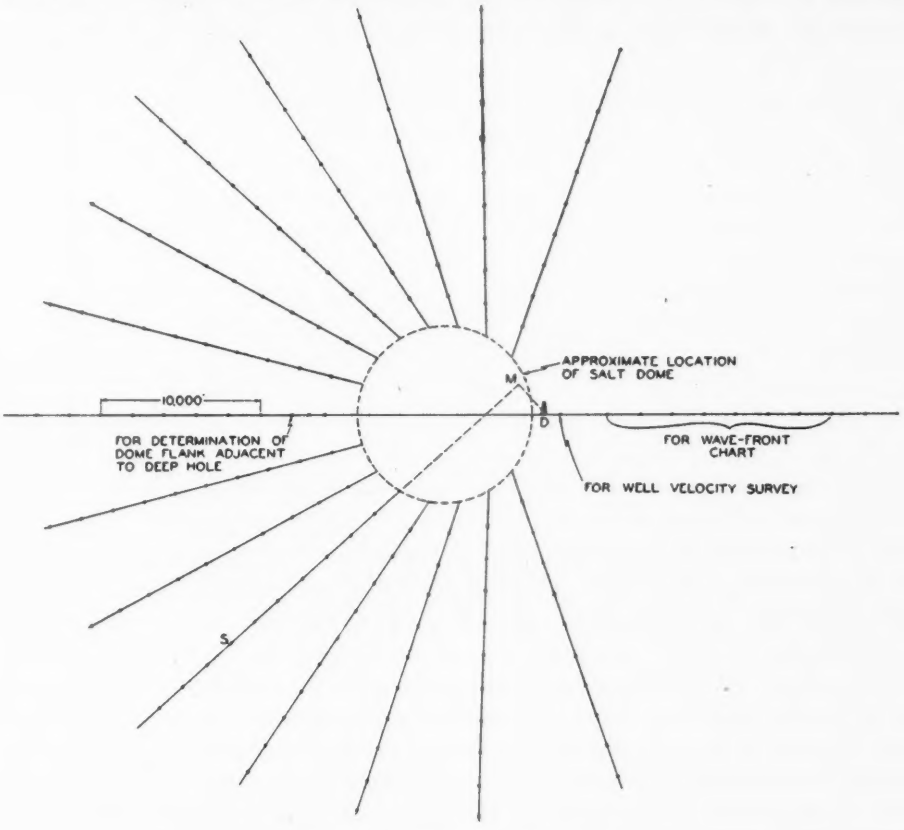

FIG. 6. Shotpoint distribution plan.

position to be actually tangent to the dome. A test of this question can be applied by constructing as many horizontal traces of aplanatic surfaces as desired at levels of vertical tangency. Comparison of these traces with the approximate contour map of the dome not only will test the question of tangency horizontally, but also will supply a more accurate position of the dome surface.

Thus, using vertical and horizontal traces in combination, points of tangency

can be located, following a method of successive approximations. Since the determination of a point on an aplanatic surface near the point of tangency fixes the position of the dome to a relatively high order of accuracy, the first approximation often suffices to determine the dome surface to as high a theoretical precision as is useful in consideration of residual errors in observed data and velocity parameters. This statement applies particularly for profiles opposite the detector (Fig. 6) where the horizontal components of refraction are comparatively small and can be quite accurately estimated. For profiles on the same side of the dome as the detector, the horizontal components of refraction are relatively large and difficult to estimate accurately before determination. Accordingly, shotpoints on the side of the dome toward the detector tend to require more successive

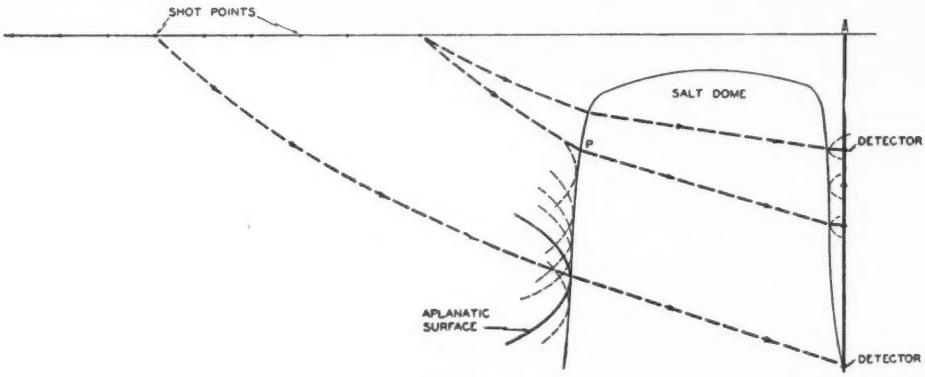

FIG. 7. Profile of dome, constructed tangent to a set of aplanatic surfaces.

trial constructions of vertical and horizontal traces of aplanatic surfaces in order to locate the dome boundary. Under any conditions of shooting arrangement or poor first-trial approximations, the successive approximations finally lead to good results, which can be expressed on a contour map.

A variation in technique is applicable to finding the section of the dome adjacent to the deep hole. From a shotpoint on the opposite side of the dome, recordings are made to the detector at various depths in the hole (Fig. 7). The section of the opposite side of the dome having been determined, the wave path to any detector level can be approximately drawn. The location and travel time to an approximate piercing point P of this path through the dome boundary opposite the detector then can be ascertained. Accurate location of this piercing point is unnecessary, due to Fermat's principle. Then, the problem is reduced to the simple two-dimensional case illustrated in Figure 1, by considering the piercing point to be the source of the seismic wave, after subtracting the travel time from the shotpoint to the piercing point. An appropriate velocity for the section between the detector and the dome is assigned, and an aplanatic surface constructed for the side of the dome adjacent to the detector. The set of such aplanatic sur-

faces, which can be determined from observations at a number of detector levels, serves to determine the section of the dome adjacent to the deep hole. The results thereof can be incorporated into the contour map of the dome to make it more complete.

A second detector may be suspended in the deep hole, some distance above the one in the flank of the dome, so that dual recordings are made for all shots fired. A few shots suffice to determine the conditions around this detector by the technique just described. A reverse application of this technique, combined with the methods described for the detector situated in the salt flank, suffice to yield a complete supplementary set of aplanatic surfaces to locate the dome boundary. Thus, the use of a second detector strengthens the final results or reduces the number of shotpoints required.

If a deep hole is drilled adjacent to a salt dome, but does not penetrate the dome boundary, the well detector must of necessity be situated an unknown short distance away from the dome boundary. This fact introduces another degree of freedom into the problem. The observational data would not permit determination of the distance of the dome as a whole with respect to the detector. However, the shape of the dome can be quite satisfactorily determined if the dome surface adjacent to the detector is assumed in an approximately correct position, and account is taken of the travel time between the detector and the dome. Further, if there is one known point on the dome, fixed by well data, this additional information makes the problem of mapping the dome determinate. The position of the dome adjacent to the detector and the wave travel time across the intervening space can be ascertained by the technique described above. Then the determination of the dome boundary can be made as before, in treating the emergence point of seismic waves from the dome as the receiver, and accounting for the travel time from this point to the detector. Errors in determining the conditions near the detector may be relatively large, due to a possible poor value for salt velocity for this case, but such errors are largely cancelled in determining the boundary of the dome as a whole.

In the execution of such a survey as described in this article, essentially the same procedures of handling a detector in the deep hole as for a well velocity survey are used. However, it is desirable to have both horizontal and vertical detector elements in the well detector in order to obtain good recordings of all waves, some of which are received in a nearly vertical direction and some in a nearly horizontal direction. Use of two detectors suspended say 1,000 to 2,000 feet apart is advantageous. Preparations must allow for the possibility of the survey requiring from several days up to two weeks or more. Consequently, precautions must be taken to guard the hole and detector against caving and settling mud. Cased holes are most suitable for this reason.

Ordinarily, it is advisable to have a large proportion of the required shot holes drilled in advance to avoid delays in operations while waiting for them to be drilled. Measurements of positions of all shot holes, relative to the deep hole,

should be good to within ± 20 feet, but greater accuracy is relatively unimportant because larger errors arise from other sources. The horizontal position of the detector at depth must also be known to this accuracy, so a directional survey of the hole usually is desirable for best results.

Results from a number of such surveys have been tested by subsequent drilling, showing that the seismograph results were accurate to within 100 feet in several cases. In other cases, results were not so closely checked. Overhang has been successfully mapped. The most serious discrepancies with respect to the dome boundary have been found at depths of the order of, or greater than, the depth of the well detector. Naturally, the most accurate results are obtained at positions on the dome surface which are in a symmetrical position with respect to, or close to, a known point on the dome surface. Some uncertainties are introduced in outlining the top of a dome if cap rock of unknown distribution is present.

RESIDUAL GRAVITY IN THEORY AND PRACTICE*

W. RAYMOND GRIFFIN†

ABSTRACT

A precise definition of residual gravity is given and in a form most suitable for numerical application. Some pains are taken to show that the residual-gravity picture one obtains depends on the method used in obtaining it and that there are many ways in which this may be done. Several examples from actual work on developed oil fields are given in the form of figures and maps to bear out the above statement. Conclusions are drawn as to the relative order of sensitivity of several factors entering into the computations in determining a given residual picture. Factors considered in this paper are (1) size of unit figure, (2) kind (or shape) of unit figure, (3) density of reference net; that is, number of reference points per unit area, and (4) sensitivity of reference points to lateral displacement on gravity map.

INTRODUCTION

Residual gravity is a term arising out of the fact that the conventional gravity map reflects the superposition (or combining) of local gravity fields (anomalies), due to local geological structures, upon those of regional gravity fields caused by regional geological structure.

The construction of a residual gravity map is a process by which one shows only the residue of the gravitational field due to local structure, that is, a process by which one removes the *regional* gravity effects.

Originally, the preparation of such a map was accomplished by simply drawing smooth contour lines so that they best represented the regional picture. Then the departure of the actual contour from the smoothed one was taken as being the residual gravity at that point. These departures were then scaled off and recorded on another map. This map was then contoured by drawing in the lines of equal gravity intensity.

It is not difficult to see how largely the personal equation would enter into this method. Since no papers have as yet appeared in print on this subject, as far as the writer knows, it is difficult to determine whether or not any residual maps are still prepared by the "smoothed-contour" method.

It is believed, however, that practically all residual maps now prepared use some numerical method to remove the regional effect. Due to the above-mentioned lack of articles on this subject, one can only surmise that it is highly probable that each company has its own individual method. Therefore, it is reasonable to suppose that the residual gravity map of one company is not strictly comparable to that of another company for the same area.

It is the purpose of this paper to show, by theory and by example, that the residual map one obtains of a given area depends very largely on the method used

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in obtaining it. Each method may be sufficient for the task in hand, but, it cannot be too strongly emphasized, the maps so obtained for the same area are not completely comparable.

A QUANTITATIVE DEFINITION OF RESIDUAL GRAVITY

Residual gravity may be quantitatively defined in a large number of ways, theoretically, in an infinite number of different ways.

A practical definition is the following and is the one which will be used here:

$$\Delta g = g(o) - \bar{g}(r), \tag{1}$$

where $g(o)$ is the gravity value at a given point on the gravity map, and

$$\bar{g}(r) = \frac{1}{2\pi}\int_{o}^{2\pi} g(r, \theta)d\theta \tag{1a}$$

is the *average* gravity value at the radial distance r from the point where the gravity value is $g(o)$.

The geometrical interpretation of (1a) is that the average value, $\bar{g}(r)$, is obtained by going around a circle of radius r, having $g(o)$ as its center, and forming the sum of the products of $g(r, \theta)$ and $d\theta$ for an infinite number of infinitesimally small $d\theta$'s. The result of the above is then divided by 2π.

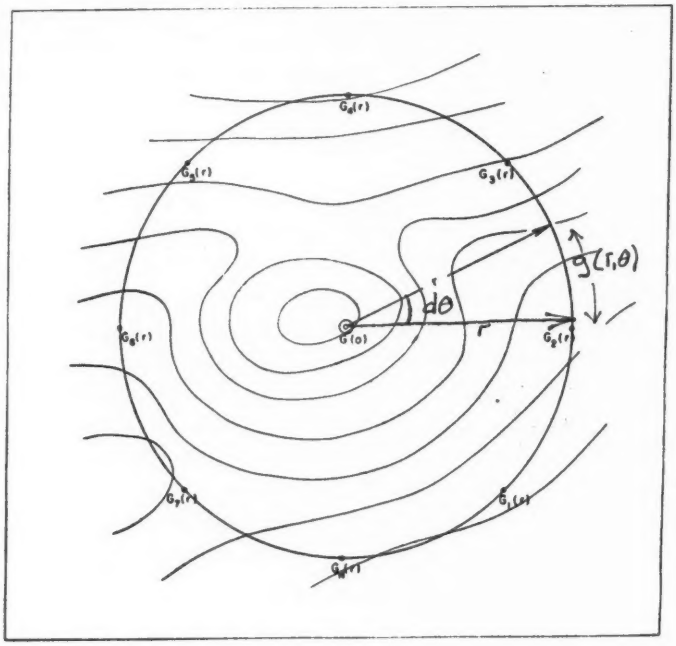


FIG. 1. Schematic representation of application of equation (1).

Since, in general, an integrable form of $g(r, \theta)$ is not known, the geophysicist must adopt some numerical method; further, the numerical method chosen must be one economical of time. One such method is to form the arithmetical average of a finite number of points about the circumference of a circle of radius r, or

$$\bar{g}(r) = [g_1(r) + g_2(r) + g_3(r) + \cdots + g_n(r)]/n \qquad (1b)$$

for n points.

It should be noted at this point that (1a) and (1b) could have been defined as being about other figures than a circle. It could have, for example, been defined as being about long, narrow rectangles; in fact, in some cases it is conceivable that some such averaging figure *should* be chosen.

A study of Figure 1 may help make the definitions of equations (1a) and (1b) clear.

DEDUCTIONS FROM THE DEFINITION

The residual gravity, Δg, may be a positive, zero, or negative quantity depending upon whether or not the value, $g(o)$, at the point under study, is greater than, equal to, or less than the average regional background determined by $\bar{g}(r)$.

It is desirable now to study the two limiting cases of equation (1) that obtain when reference circles of infinitesimally small and infinitely large radii are considered.

Case I ($r = o$).—For $r = o$, the average value $\bar{g}(o)$ becomes coincident with that value, $g(o)$, at the point under study, or $\bar{g}(o) = g(o)$. Therefore, from equation (1),

$$\Delta g = g(o) - g(o) = o; \qquad (2)$$

that is, the *residual* gravity at a point having the gravity $g(o)$ is zero when an infinitely small reference circle is used.

Case II ($r = \infty$).—For this case, $\bar{g}(\infty) = o$ if the gravitational field under study is produced by a mass finite in size. This follows from the fact that the gravitational field of a finite body an infinite distance away is zero. Upon now substituting $\bar{g}(\infty) = o$ in equation (1), one obtains

$$\Delta g = g(o) - o = g(o) = (\Delta g)_{max}. \qquad (3)$$

This means that, if no disturbing bodies were present, the residual gravity would approach that gravity value due solely to the local body when the radius of the reference circle was made indefinitely large. In actual practice, as will be shown later in the applications, this maximum value of $\Delta g = g(o)$ is usually attained within a radius of five miles of the anomaly. For distances greater than five miles, the maximum residual value may be passed and the residual gravity decrease. This last is believed to be due to the presence of neighboring bodies.

From a consideration of Cases I and II, it is thus clearly evident, from theory, that the residual gravity at a given point depends upon the size of the reference figure chosen to obtain the regional effect, that is, according to the definition as

given by equations (1), (1a), and (1b), the residual gravity is a function of the radius. This is thoroughly brought out in the following examples and applications.

For an idea of how the residual gravity for certain simple, geometrical bodies would vary with the radial distance from a point directly over the body, one would profit by a study of a set of curves prepared and published several years

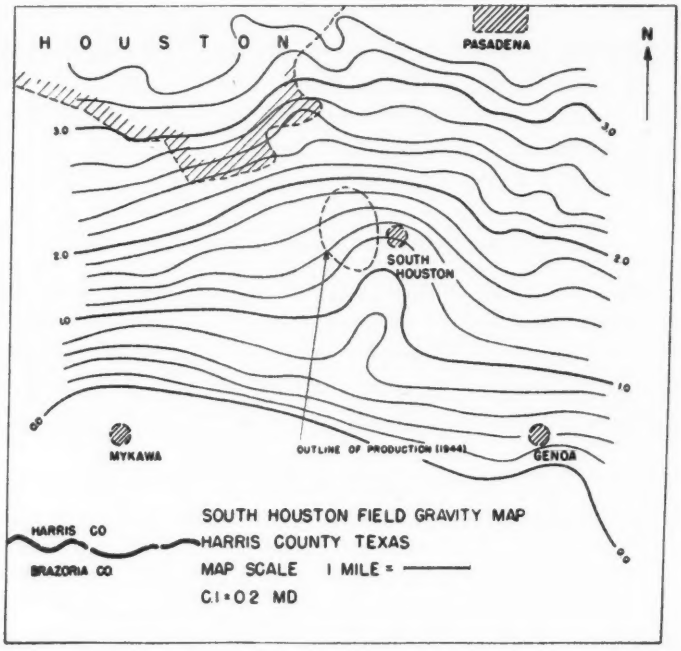


FIG. 2. Conventional gravity map of South Houston field and adjacent area. Contour interval=0.2 millidyne.

ago by Dr. Nettleton.[1] If his figure for the lateral variation of gravity of spheres and cylinders be turned up-side-down and viewed from the reverse side, then they will give the residual gravity, as defined in equation (1), of the bodies for which the curves are in non-dimensional form and such that the residual varies between zero and unity. This is the same as if the residual gravity had been divided by the maximum residual. Thus,

$$\Delta g/\Delta g_{max} = [g(0) - \bar{g}(r)]/g(0) = 1 - [\bar{g}(r)/g(0)] \qquad (4)$$

where his $f(x/z)$, corresponds to $\bar{g}(r)/g(0)$.

In fairness it should perhaps be mentioned that, although no articles have come to the writer's attention on the method of making residual gravity maps, several articles have appeared which are closely related to, and border upon, the

[1] L. L. Nettleton, "Gravitational and Magnetic Corrections," *Geophysics*, VII (1942), 293–310.

subject. These include the one by Nettleton already referred to, two by Kogbetliantz[2,3] and one by Hughes.[4] The last three are in a highly mathematical form and not suited for an economical application. Pirson[5] does mention the word "residual" but seems to prefer the phrase "gravitational focusing." His *qualitative* discussion of residual gravity is significant and valuable. His *quantitative* method,[6]

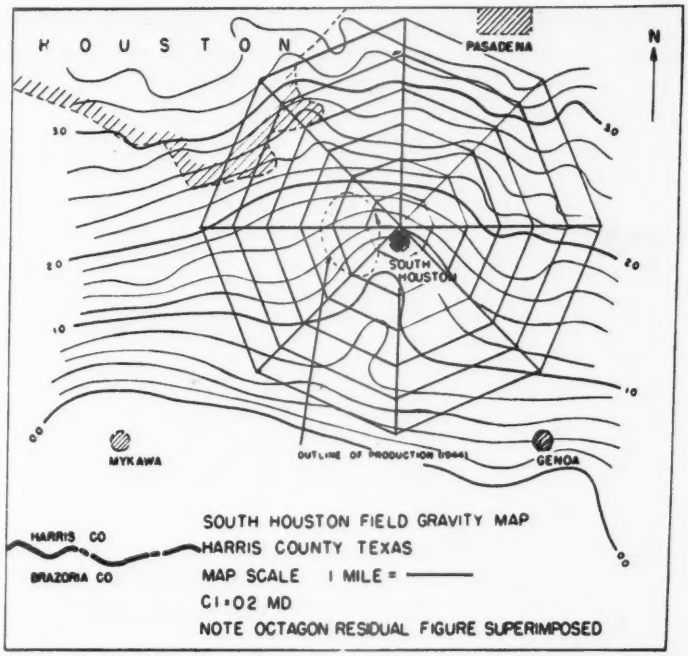


FIG. 3. Same as Figure 2 but with superposition of family of concentric octagons.

however, is based upon a method which apparently has not been able to meet successfully the test of critical analysis[7] and thus the figures showing contours labeled as depths are open to question.

APPLICATIONS

Graphs of Residual Gravity vs. *Radius of Unit Residual Figure for Point Over Center of Anomaly.*—The following numerical studies of residual gravity have all

[2] E. G. Kogbetliantz, "Quantitative Interpretation of Magnetic and Gravitational Anomalies," *Geophysics*, IX (1944), 463–493.

[3] E. G. Kogbetliantz, "Estimating in Gravity Prospecting," *Geophysics*, XI (1946), 195–210.

[4] D. S. Hughes, "Analytic Basis of Gravity Interpretations," *Geophysics*, VII (1942), 169–178.

[5] S. J. Pirson, "Present Day Geophysical Exploration for Oil," *Part 3, Oil Weekly*, March 31, 1947, pp. 37–40.

[6] S. J. Pirson, "Quantitative Interpretation of Gravity Meter Surveys," *Oil Weekly*, April 16, 1945, pp. 34–36.

[7] D. C. Skeels, "Ambiguity in Gravity Interpretation," *Geophysics*, XII (1947), 43–56.

been made on salt structures in the neighborhood of Houston, Texas. This choice was made because of already published geophysical[8] and geological studies[9] for the South Houston and Katy fields with which one may correlate the residual-gravity features.

Figure 2 is a map of the gravity of the South Houston field and its neighborhood. The contour interval is 0.2 millidyne.* Figure 3 is the same map with the addition of the system of concentric unit figures (octagon) used in securing residual-gravity values at the center point. Figure 4 shows the results of such

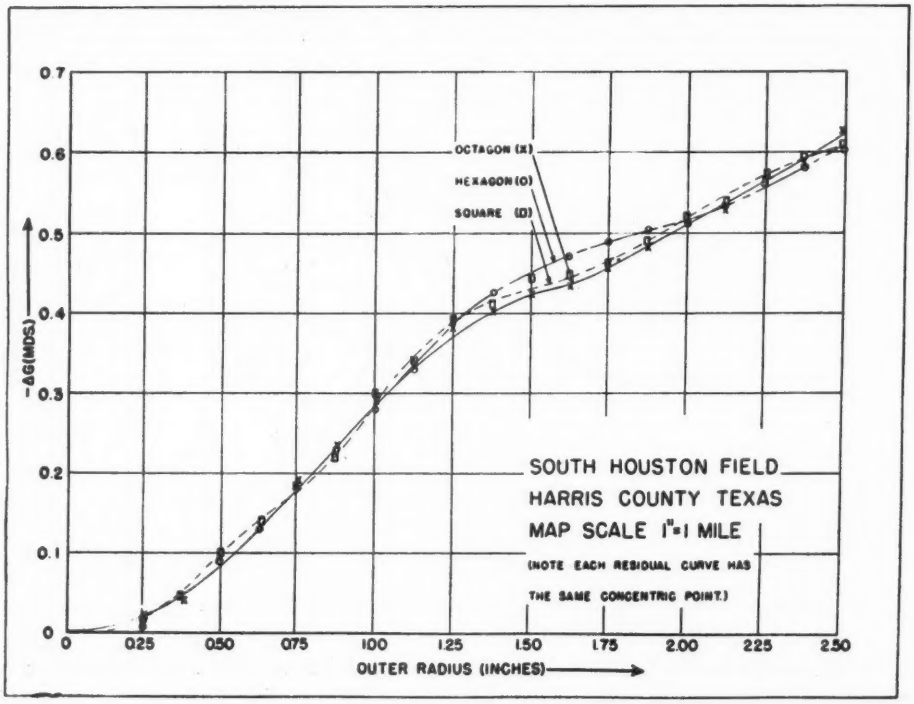


FIG. 4. Graph of variation of residual gravity with outer radius of residual figure for the South Houston field. Residual figures used were square, hexagon, and octagon.

analysis for circles of varying radii and from averaging four, six and eight equidistant points on a given circle, that is, squares, hexagons, and octagons. The residual gravity, Δg, has been plotted against the outer radius of the figure used. Since the map scale was 1 inch = 1 mile, the radial values correspond numerically to the full-scale values in miles.

[8] J. Bryan Eby, "Geophysical History of South Houston Salt Dome," *Bulletin A.A.P.G., 29* (February, 1945), 210–214.

[9] "Geology of Katy Field, Waller Co., Texas," *Bulletin A.A.P.G., 30* (February, 1946), 157–180.

* In this paper the term "millidyne" implies "millidyne per gram" and is equivalent to "milligal."

Since the density of salt is less than that of the surrounding sediments, its residual is negative. In order to plot the values upward rather than downward, the ordinate had to be in terms of $-\Delta g$. It is to be emphasized that the analysis given in this graph is for one point only and that point is directly over the center of the South Houston salt dome.

Thus, it is to be observed that *if* a residual map of the area were to be made using squares of 1-inch outer radius, then the *maximum* residual *would* have been

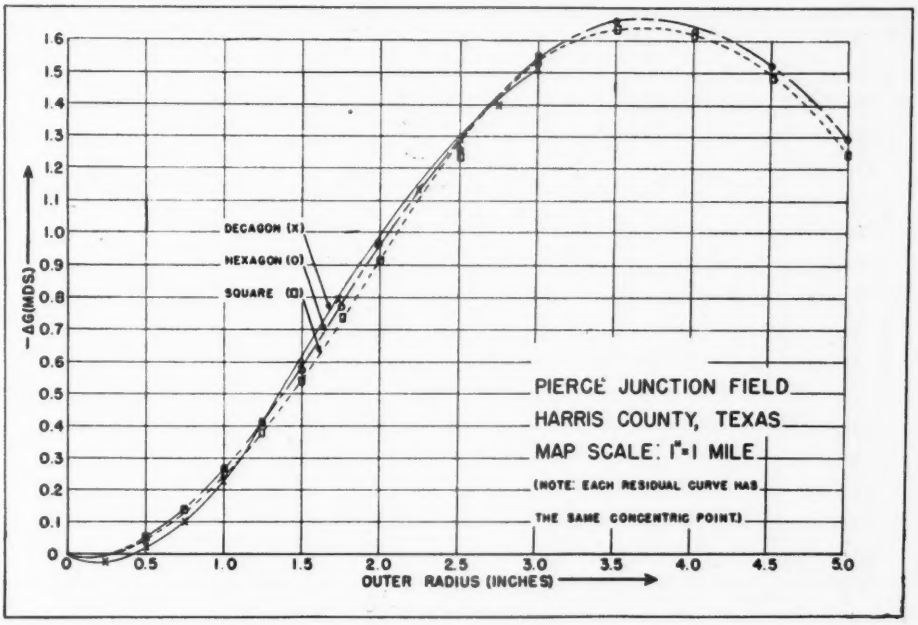


FIG. 5. Graph of variation of residual gravity with outer radius of residual figure for Pierce Junction field. Residual figures used were square, hexagon, and decagon.

found to be -0.3 millidyne. If squares of 2-inch outer radius had been used, then the maximum residual would have been -0.52 millidyne. It is therefore seen that the amount of residual one obtains at a given point varies greatly with the *size* of the unit figure used. It will vary from nothing for a zero-sized figure to a maximum value for some certain finite-sized figure.

The effects of the *kind* of figure will now be examined, that is, for a circle of a given radius, the effects of averaging different numbers of points on it will be studied. In Figure 4 of the South Houston field, it is seen that the maximum variation in averaging eight points instead of four amounts to only about 0.05 millidyne. This occurs at a radial distance of about 1.67 inches from the center of the anomaly. The kind of figure used, then, is only of secondary importance relative to the *size* of figure used.

Figure 5 is a similar analysis on the Pierce Junction salt dome but the radial distance has been doubled to 5 miles and a decagon has been used in place of a hexagon. Again one sees the primary importance of the radius and the secondary importance of the number of points averaged. The maximum value obtained over the center of the salt dome for a decagon of 1.5-inch outer radius would have been −0.6 millidyne while for one of 3-inch radius, the residual would have been −1.51 millidyne, a value *more* than double the −0.6 millidyne even though the radius has only been doubled. The maximum difference between averaging four

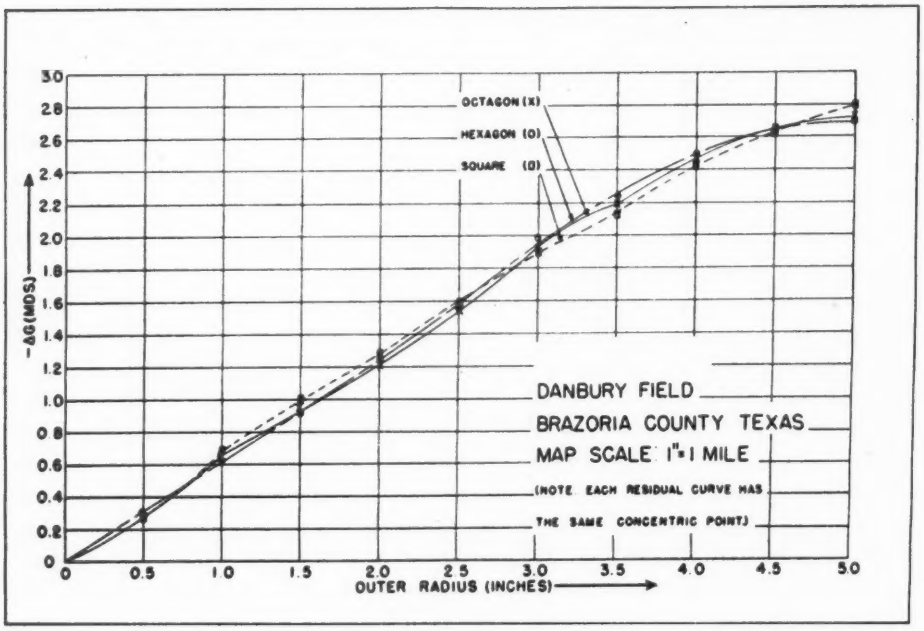


FIG. 6. Graph of variation of residual gravity with outer radius of residual figure for Danbury field. Figures used were square, hexagon, and octagon.

points and ten points is about 0.10 millidyne and occurs at about 1.75-inch radial distance.

This figure also brings out clearly the non-linear relationship between the residual value and the radial distance. A maximum value of about −1.65 millidyne is attained at a radial distance of 3.5 inches = 3.5 miles. The decrease in residual gravity beyond this point is believed to be due to neighboring positive anomalies.

It is interesting to note the point marked X on the decagon curve at $r = 0.25$ inch. It will be observed that it represents a *positive* residual value. This point is not in error but represents the picking up of the effect of the very shallow cap rock (at a depth of about 600 feet to the top and about 300 feet thick). Cap rock has a density greater than that of the surrounding sediments and thus has a posi-

tive residual effect. It will be observed that the other two curves in the same neighborhood tend to exhibit the same effect.

Figure 6 is a similar study of the Danbury salt dome in Brazoria County, Texas, about 40 miles south of Houston. The concentric point of the squares, hexagons, and octagons was taken as being directly over the center of the dome.

It may be noted in passing that the way the curves approach the origin indicate complete absence of cap rock and, so far as is known to the writer, this is the case.

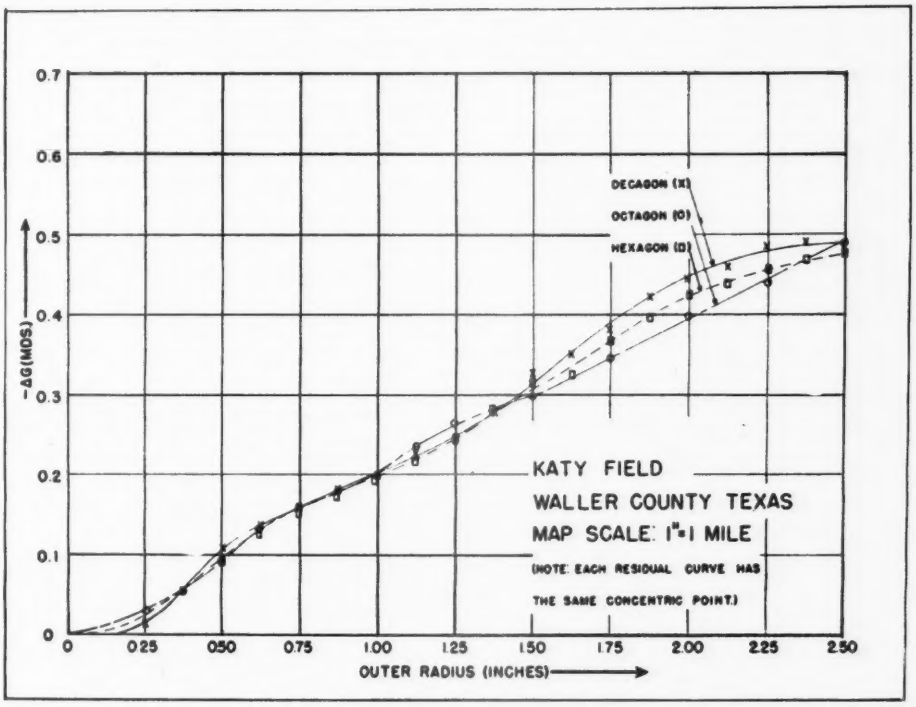


FIG. 7. Graph of variation of residual gravity with outer radius of residual figure for Katy field. Figures used were hexagon, octagon, and decagon.

In terms of the residual for a given radius, it is again seen that the kind of figure used is of secondary importance.

Figure 7 is an analysis of the Katy field, Waller County, Texas, about 35 miles west of Houston. Although, to the writer's present knowledge, no salt has been reached in drilling on the Katy structure, it is nevertheless believed to be due to a salt structure. This belief is held because the residual is a negative one and located in a region of salt domes.

In any event, the above-mentioned figure shows that again the effect of *size*

of unit residual figure predominates over that of the *kind* of unit figure but not quite so strongly as in the other examples. For an outer radius of 2 inches = 2 miles, there is a variation of the residual as obtained by a hexagon and decagon of about 0.05 millidyne or 12.5 percent of the hexagon value at that radius.

Figures 8 and 9 show the effect of displacing the concentric point from directly over the anomaly to $\frac{1}{4}$ inch = $\frac{1}{4}$ mile north, south, east, and west of the point from

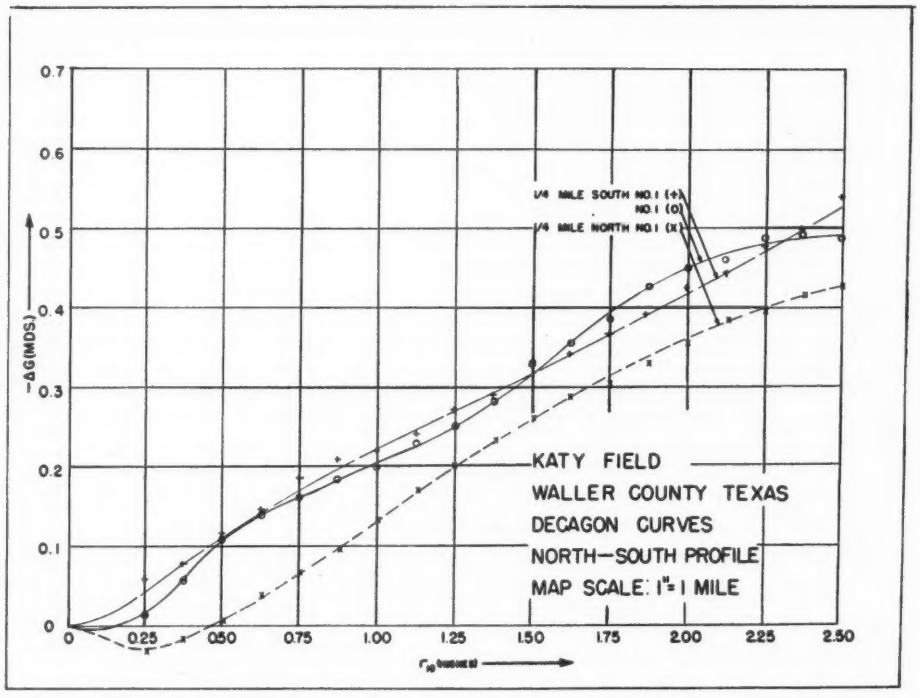


FIG. 8. Graph of variation of residual gravity with outer radius of decagon for the Katy field. The three curves constitute a north-south profile of three points spaced $\frac{1}{4}$ mile apart. See Figure 17 for location of Point 1.

which Figure 7 was secured. Figure 8 is the north-south profile obtained using decagons, and Figure 9 is the east-west profile obtained in like manner. Study of these figures indicates that the residual gravity may change as much as 0.1 millidyne in going $\frac{1}{4}$ mile, that is, by displacing concentric point $\frac{1}{4}$ inch = $\frac{1}{4}$ mile.

Figure 10 is of the Conroe field, Montgomery County, Texas. It was made to determine whether a maximum on such a curve may always be obtained, providing one continues on out to a sufficiently great radial distance. In this case it was 14 inches = 14 miles. The residual again is negative and so a salt uplift must be postulated. From the magnitude of the maximum residual, it must be a huge mass and at not too great a depth.

Residual Maps.—(1) South Houston Field, Harris County, Texas.

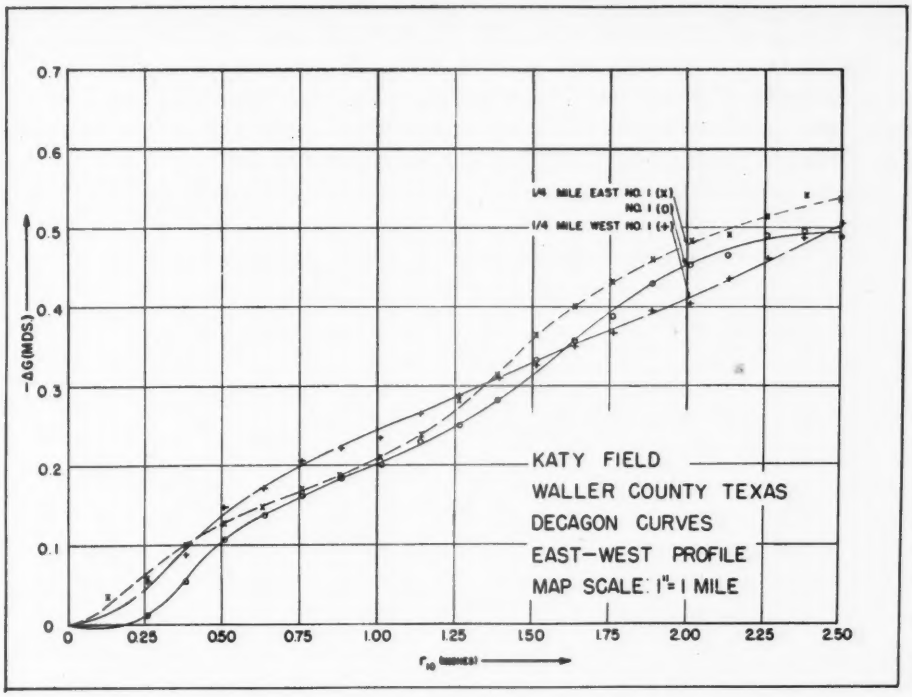


FIG. 9. Graph of variation of residual gravity with outer radius of decagon for the Katy field. The three curves constitute an east-west profile of three points spaced ¼ mile apart. See Figure 17 for location of Point 1.

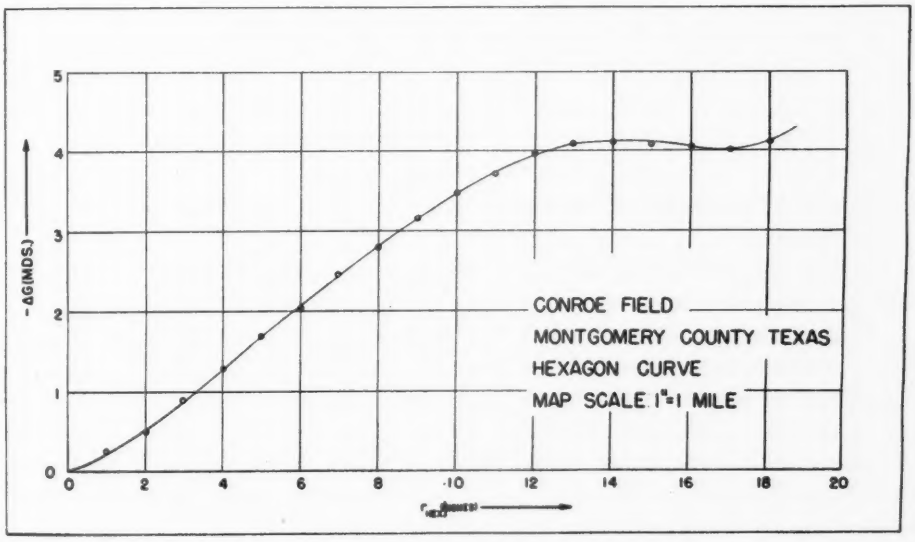


FIG. 10. Graph of variation of residual gravity with outer radius of hexagon for the Conroe field, Montgomery County, Texas.

Figure 11 is a residual map secured from the conventional gravity map by using hexagons of $\frac{3}{4}$ inch per side. A residual value was obtained every $\frac{3}{4}$ inch at equal intervals over the area. A contour interval of 0.1 millidyne has been used. The outline of production, as of 1944, is shown by the dashed line.

Figure 12 is another residual map of the same area using hexagons of 1 inch

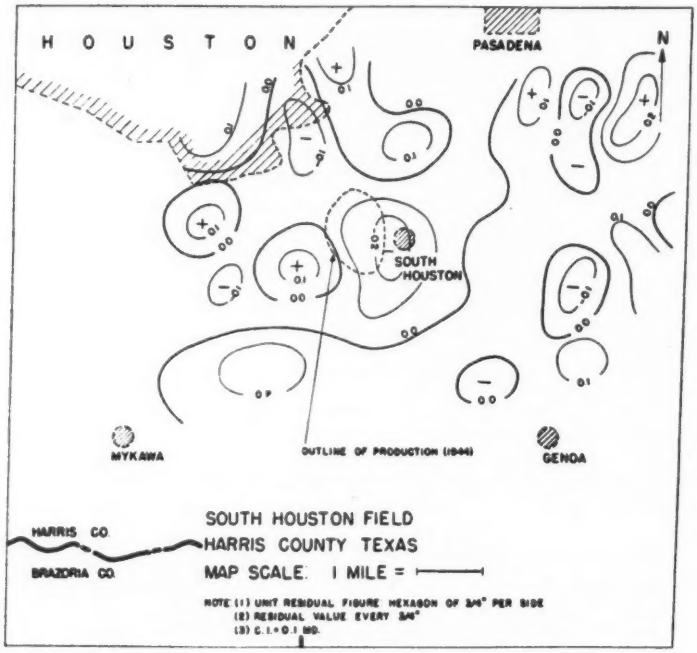


FIG. 11. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of $\frac{3}{4}$ inch per side; (2) residual value every $\frac{3}{4}$ inch; (3) contour interval=0.1 millidyne.

per side and a residual value obtained every $\frac{1}{2}$ inch. The contour interval (C.I.) is 0.1 millidyne.

Figure 13 is a third residual map obtained using hexagons of $1\frac{1}{4}$ inches per side and a residual value obtained every $\frac{5}{8}$ inch. The contour interval is 0.1 millidyne.

Figures 14, 15, and 16 are yet other residual maps of the same area obtained using, respectively, hexagons of 2 inches, 3 inches, and 4 inches per side. On these, a residual value was obtained only every inch; also, the contour interval here is 0.2 millidyne.

These residual maps may be studied profitably in conjunction with the article "Geophysical History of South Houston Salt Dome"[10] previously cited. It should be particularly noted in the above-mentioned maps that the *center* of the anomaly

[10] J. Bryan Eby, *loc. cit.*

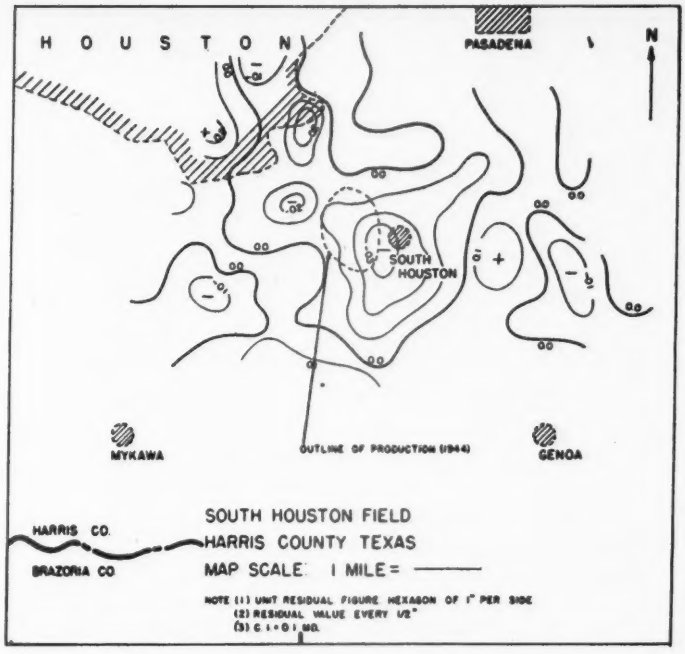


FIG. 12. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of 1 inch per side; (2) residual value every $\frac{1}{2}$ inch; (3) contour interval=0.1 millidyne.

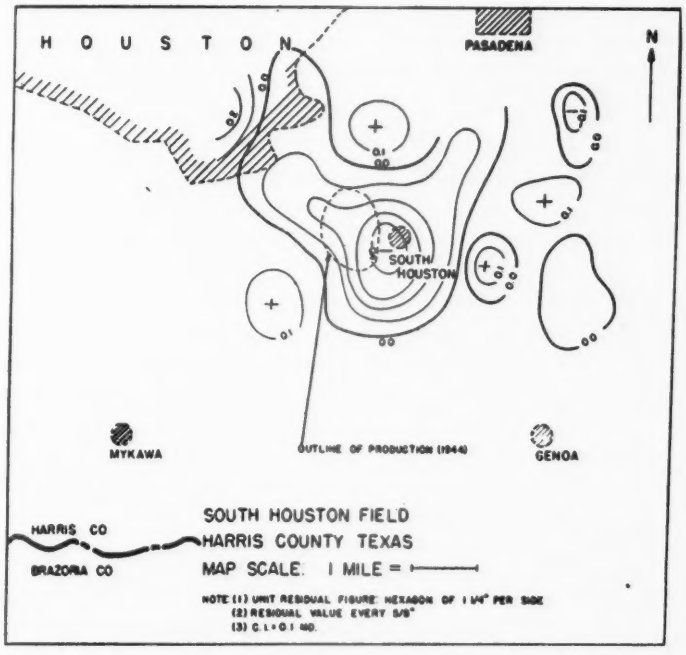


FIG. 13. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of $1\frac{1}{4}$ inch per side; (2) residual value every $\frac{5}{8}$ inch; (3) contour interval=0.1 millidyne.

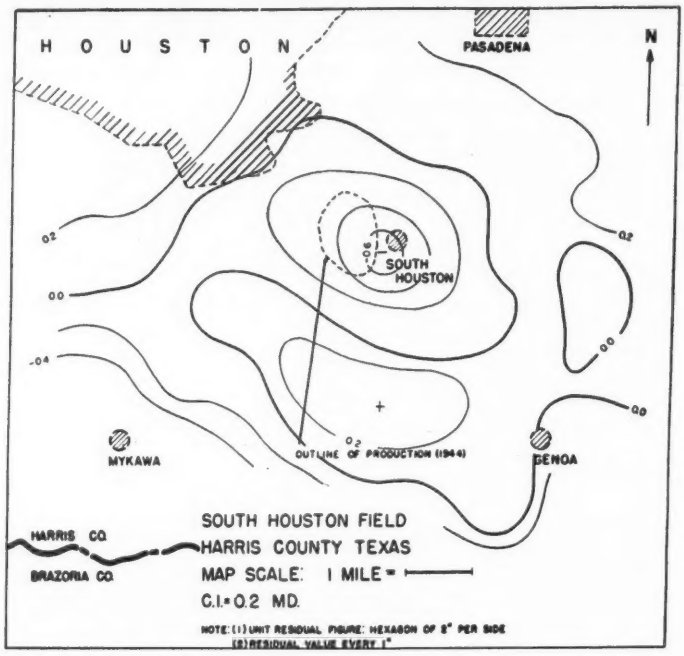


FIG. 14. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of 2 inches per side; (2) residual value every 1 inch; (3) contour interval=0.2 millidyne.

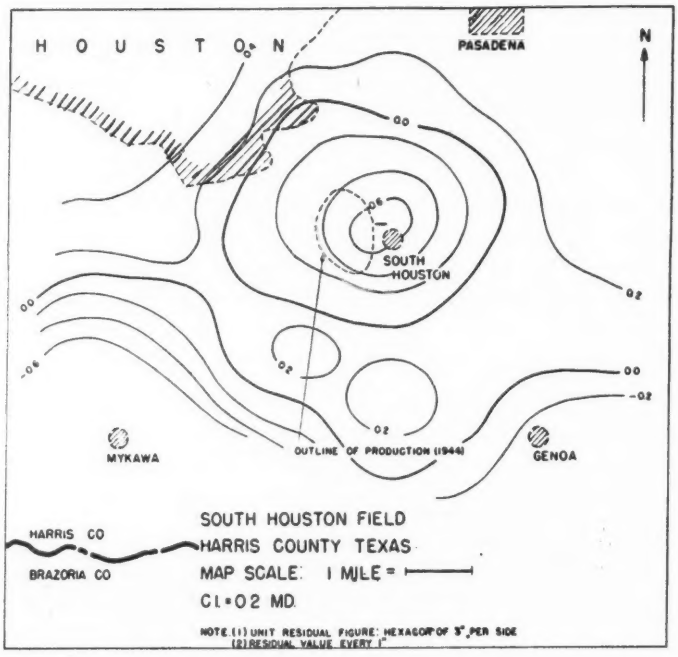


FIG. 15. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of 3 inches per side; (2) residual value every 1 inch; (3) contour interval=0.2 millidyne.

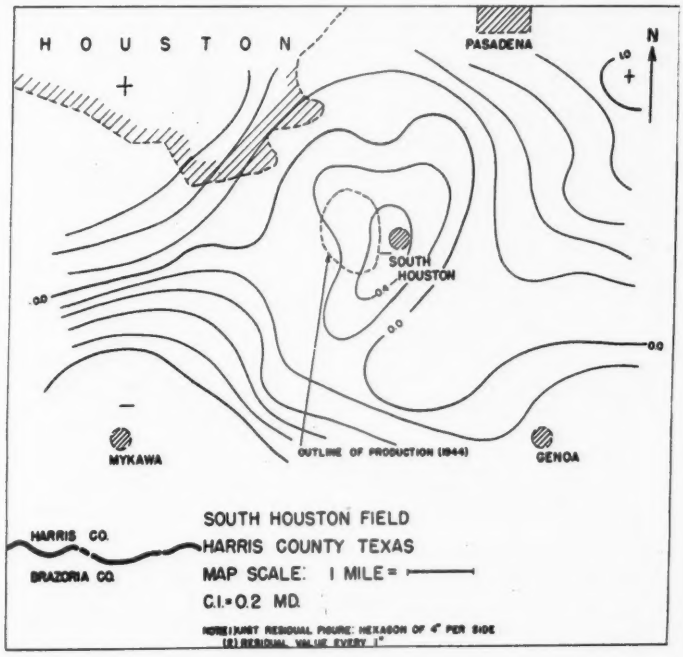


FIG. 16. Residual gravity map of South Houston field using (1) unit residual figure: hexagon of 4 inches per side; (2) residual value every 1 inch; (3) contour interval=0.2 millidyne.

is displaced practically none at all as the size of the unit residual figure is varied.

(2) Katy Field, Waller County, Texas.

Figure 17 is a conventional gravity map of the Katy field and adjacent area, with contour interval of 0.2 millidyne. On it have been placed five points. They refer to Figures 7, 8, and 9. Point 1 served as the concentric point from which Figure 7 was secured. The other points served as the concentric points from which Figures 8 and 9 were secured.

Figure 18 is a residual map of the area secured by using hexagons of $\frac{3}{4}$ inch per side and with residual values obtained at equi-spaced intervals of $\frac{3}{4}$ inch. It is desired particularly to emphasize that the contour interval here used is 0.05 millidyne. If for no other reason, this map is remarkable in that it appears to show that it is practical to contour on so small an interval.

Figure 19 is another residual map of the area but obtained by using hexagons of $1\frac{1}{4}$ inches per side and with a residual value every $\frac{5}{8}$ inch. The contour interval here is 0.1 millidyne. It is noteworthy that the picture is much smoothed out as compared to the residual of Figure 18.

Figure 20 is a third residual of the area. The sole difference of method in obtaining it, as compared to the previous residual (Fig. 19) was that of doubling the size of the hexagons used to $2\frac{1}{2}$ inches. Every other factor was held constant; namely, the ***kind*** of unit figure used (hexagon), the contour interval, and the

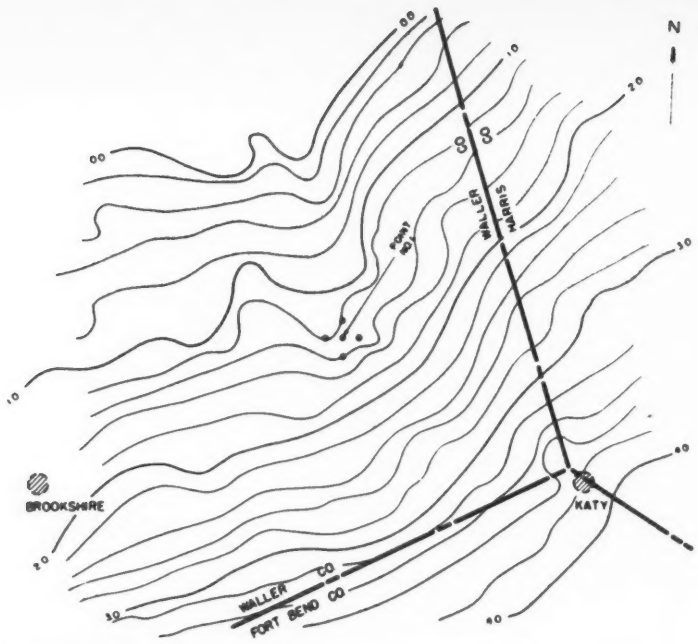


FIG. 17. Conventional gravity map of the Katy field, Waller County, Texas. Contour interval = 0.2 millidyne.

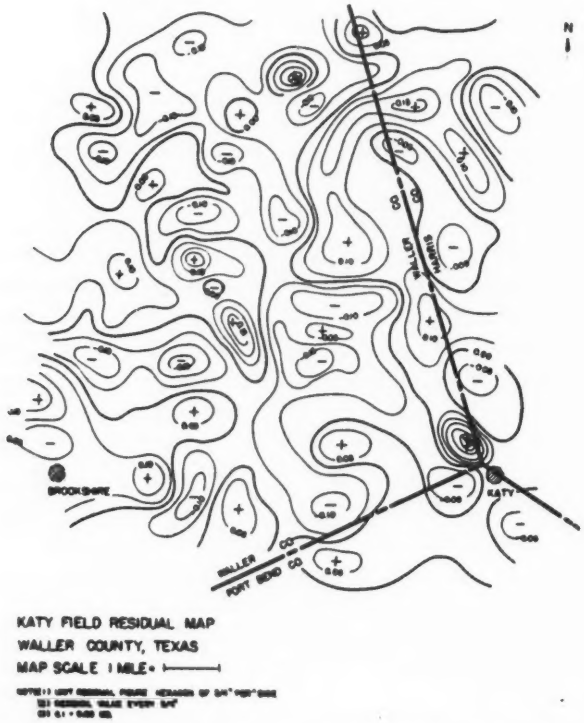


FIG. 18. Residual gravity map of the Katy field using (1) unit residual figure: hexagon of $\frac{3}{4}$ inch per side; (2) residual value every $\frac{3}{4}$ inch; (3) contour interval = 0.05 millidyne.

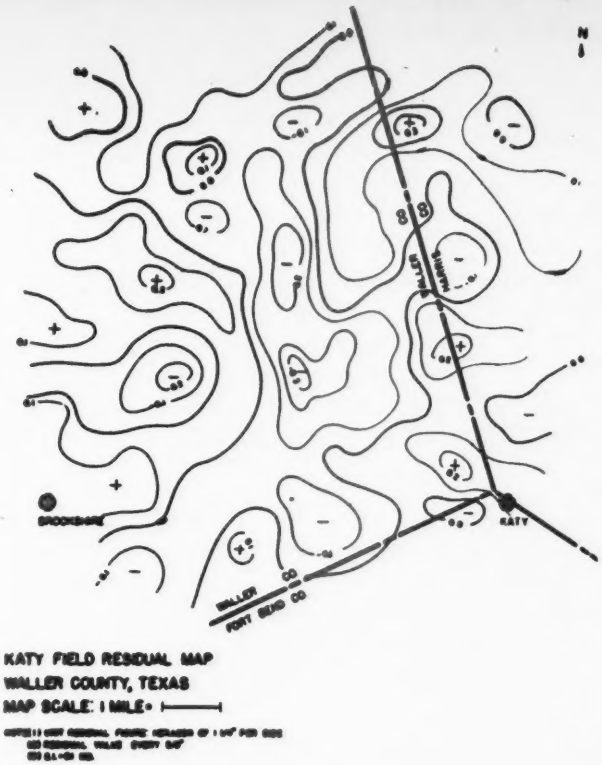


FIG. 19. Residual gravity map of the Katy field using (1) unit residual figure: hexagon of $1\frac{1}{4}$ inch per side; (2) residual value every $\frac{5}{8}$ inch; (3) contour interval=0.1 millidyne.

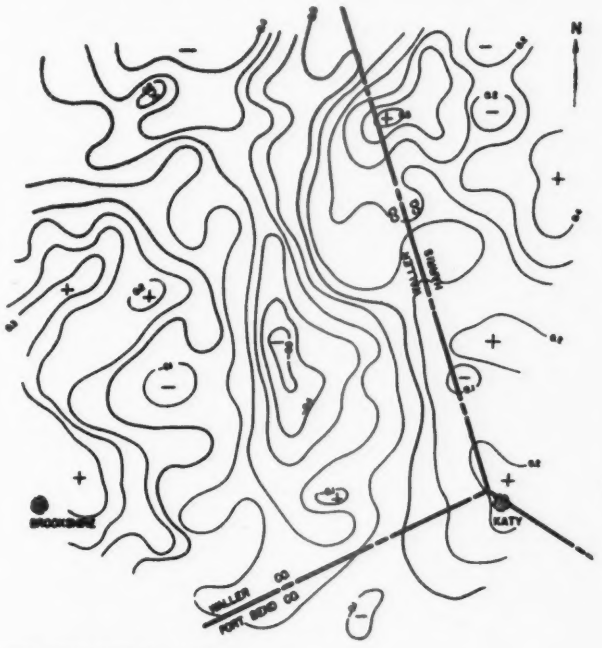


FIG. 20. Residual gravity map of the Katy field using (1) unit residual figure: hexagon of $2\frac{1}{2}$ inches per side; (2) residual value every $\frac{5}{8}$ inch; (3) contour interval=0.1 millidyne.

spacing between points at which the residuals were obtained. These points were even held coincident. The difference between Figures 19 and 20 is thus one only of the effect of *size* of the unit residual figure. As in the South Houston field it is again to be noted that the center of the anomaly is displaced practically none at all as the size of the unit residual figure is varied.

Figures 19 and 20, emphasizing the regional features, may be of particular interest to Gulf Coast geologists inasmuch as the north-west, south-east trend of the predominant minimum axis, and its divergence at the upper and lower ends, seem to suggest that here is gravitational evidence in support of Ritz's theory of rim synclines.[11]

SUMMARY AND CONCLUSIONS

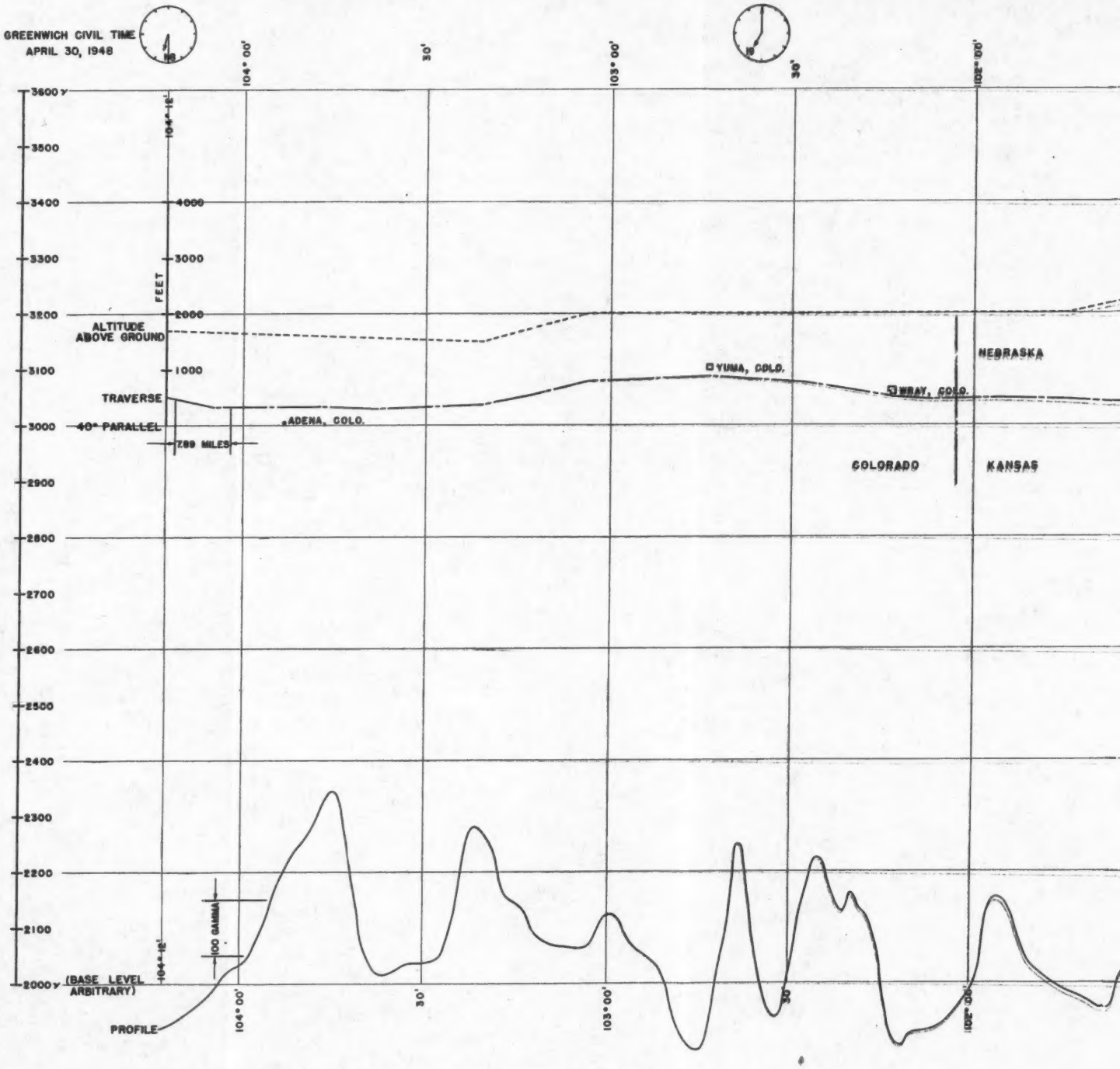
It is believed that the theory and applications, as given in this presentation of the subject, are sufficient to show the predominating importance of the size of the unit residual figure used. In comparison, the effects of kind of unit figure (that is, number of values averaged), of number of values per unit area, and of lateral displacement are seen to be secondary in nature and about equal in magnitude.

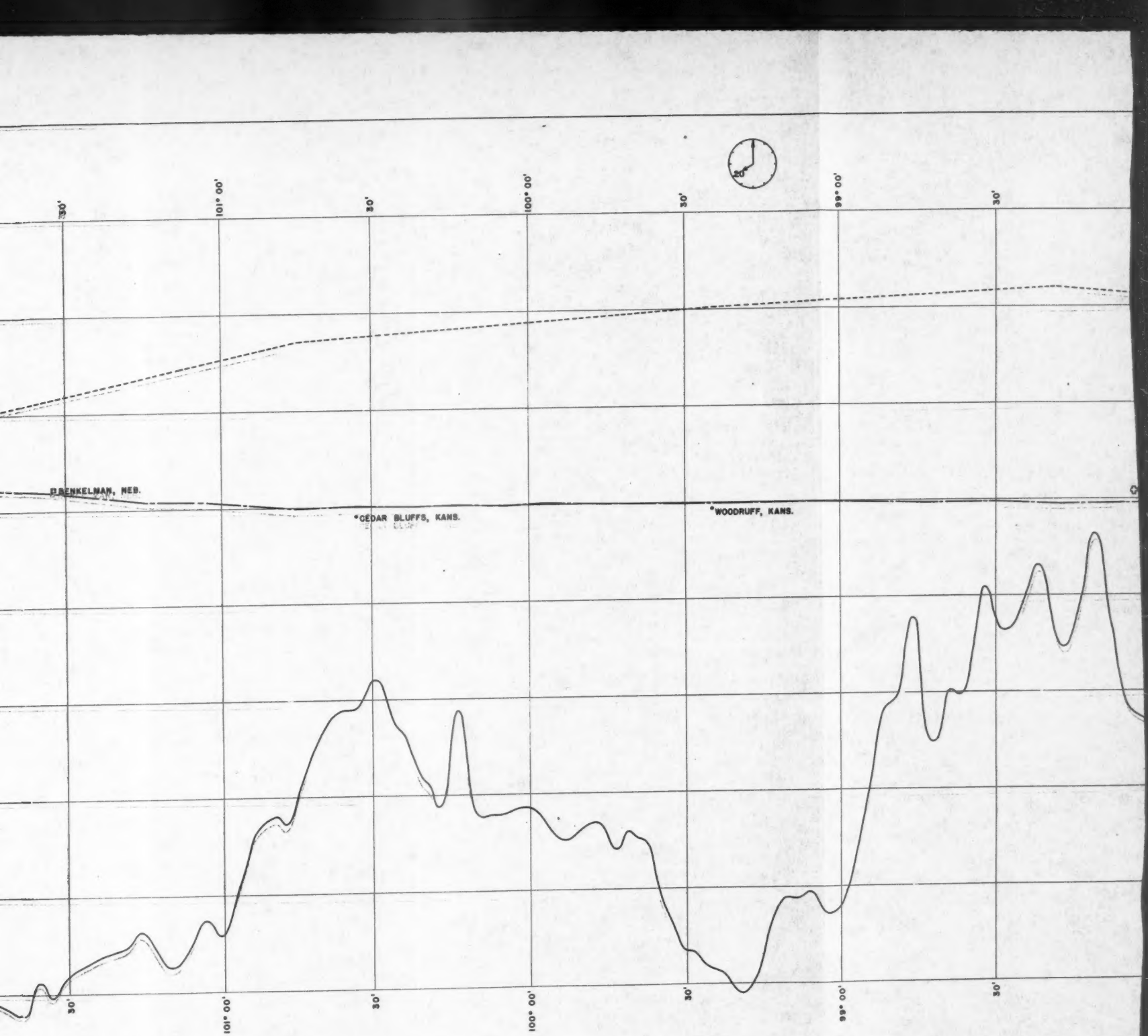
There is no practical displacement of the center of the anomaly of a residual gravity map due to varying the size of the unit residual figure.

ACKNOWLEDGMENTS

The writer wishes to thank Mr. Raymond Siever, Chief Draftsman, and Mr. Charles Beinhorn, Draftsman, for preparation of the graphs and maps, Mr. Eugene Frowe for proofreading of the manuscript, and Mrs. J. T. Wagoner for typing of the paper. The writer wishes also to take this opportunity of thanking the Robert H. Ray Co. for permission to publish the study and results of the various gravity surveys discussed.

[11] C. H. Ritz, "Gulf Coast Salt Structures," *Bulletin A.A.P.G.*, *20* (November, 1936), 1413–1438.


GREENWICH CIVIL TIME
APRIL 30, 1948
104° 00'
30'
103° 00'
30'
102° 00'
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
FEET
4000
3000
2000
1000
ALTITUDE ABOVE GROUND
TRAVERSE
40° PARALLEL
789 MILES
ADENA, COLO.
YUMA, COLO.
WRAY, COLO.
NEBRASKA
COLORADO
KANSAS
100 GAMMA
(BASE LEVEL ARBITRARY)
PROFILE


20
30'
101° 00'
30'
100° 00'
30'
99° 00'
30'
FRENKELMAN, NEB.
*CEDAR BLUFFS, KANS.
*WOODRUFF, KANS.
30'
101° 00'
30'
100° 00'
30'
99° 00'
30'

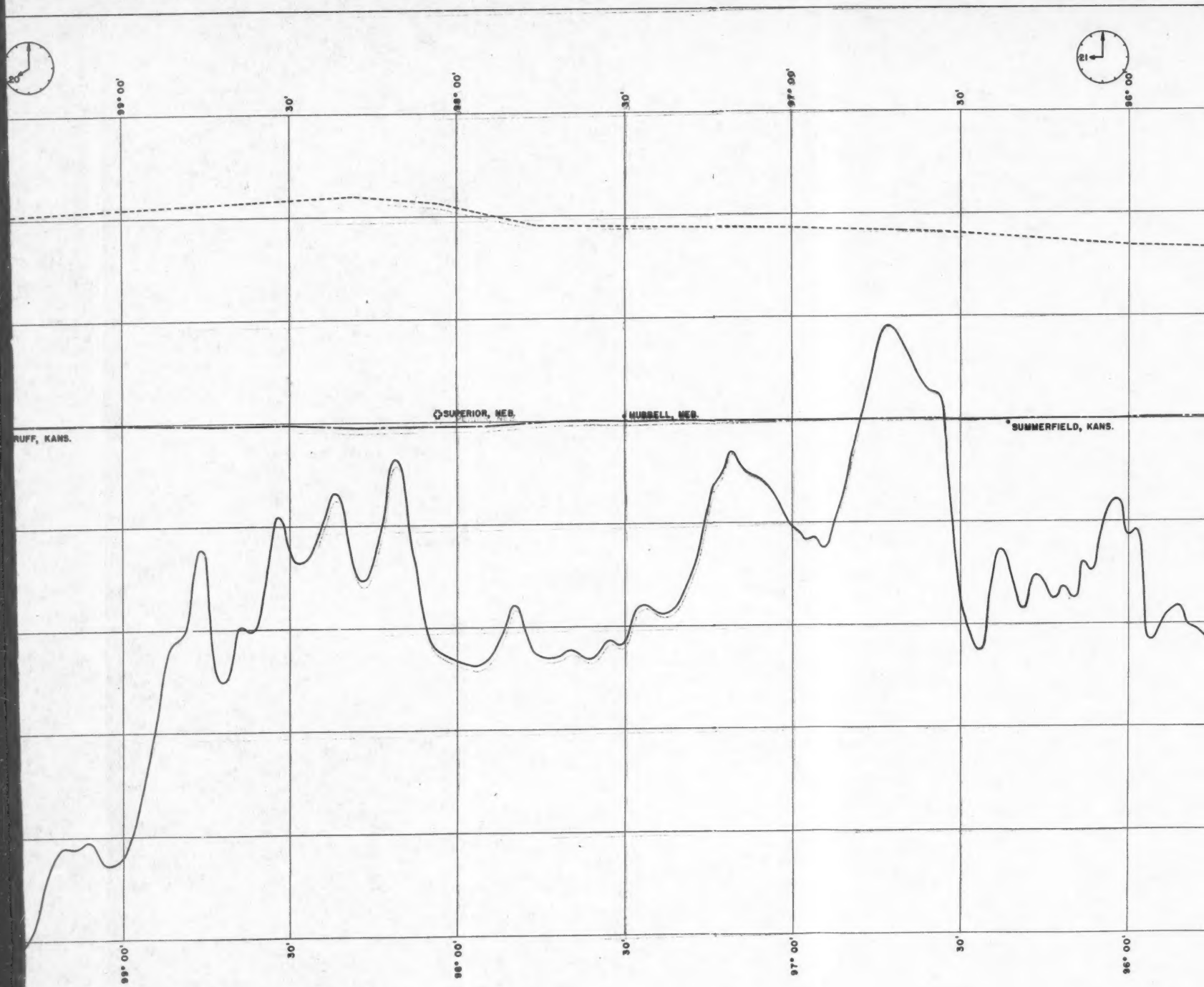
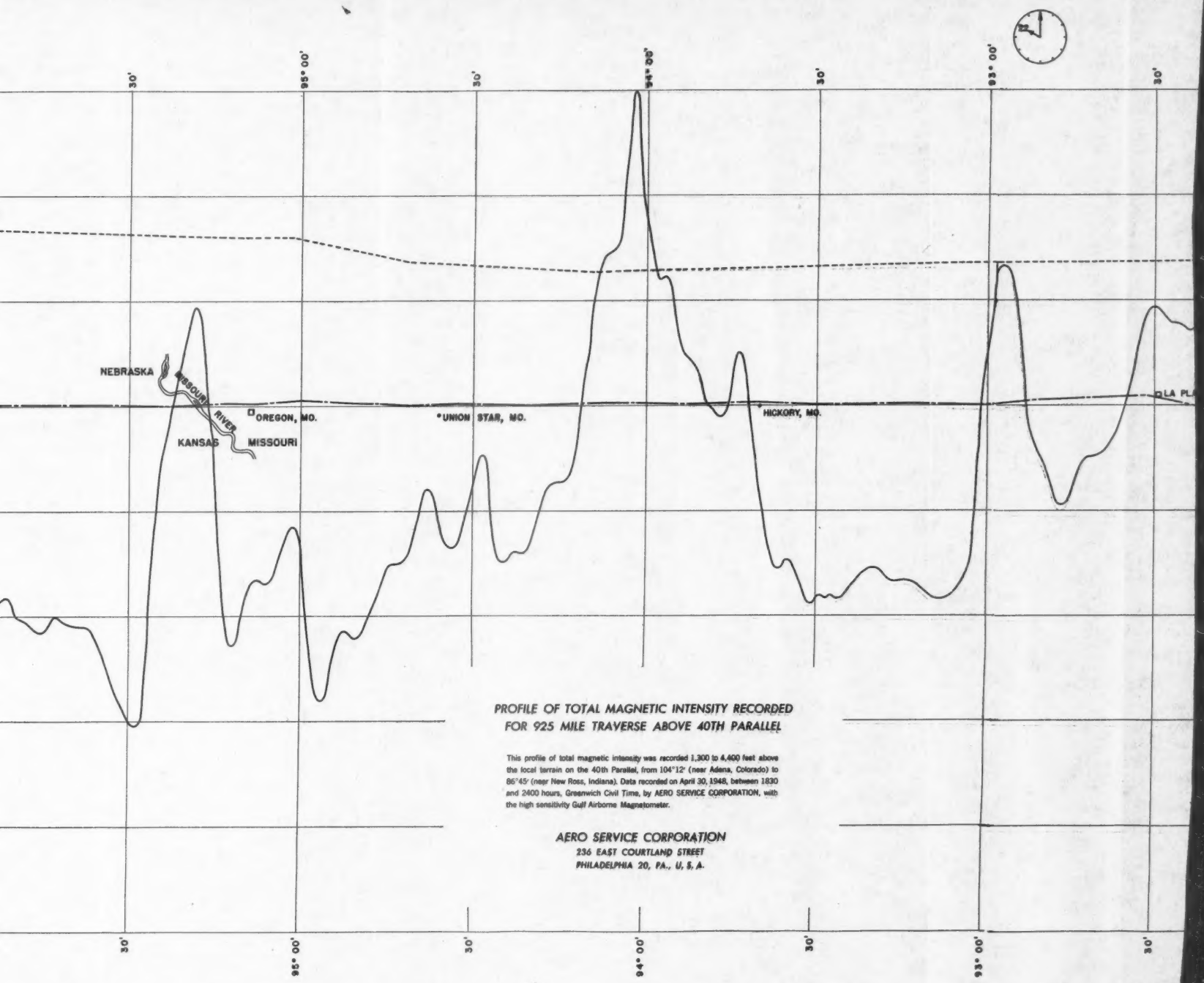


FIG. 1. Profile of total magnetic intensity recorded 1,300 to 4,400 feet above local terr

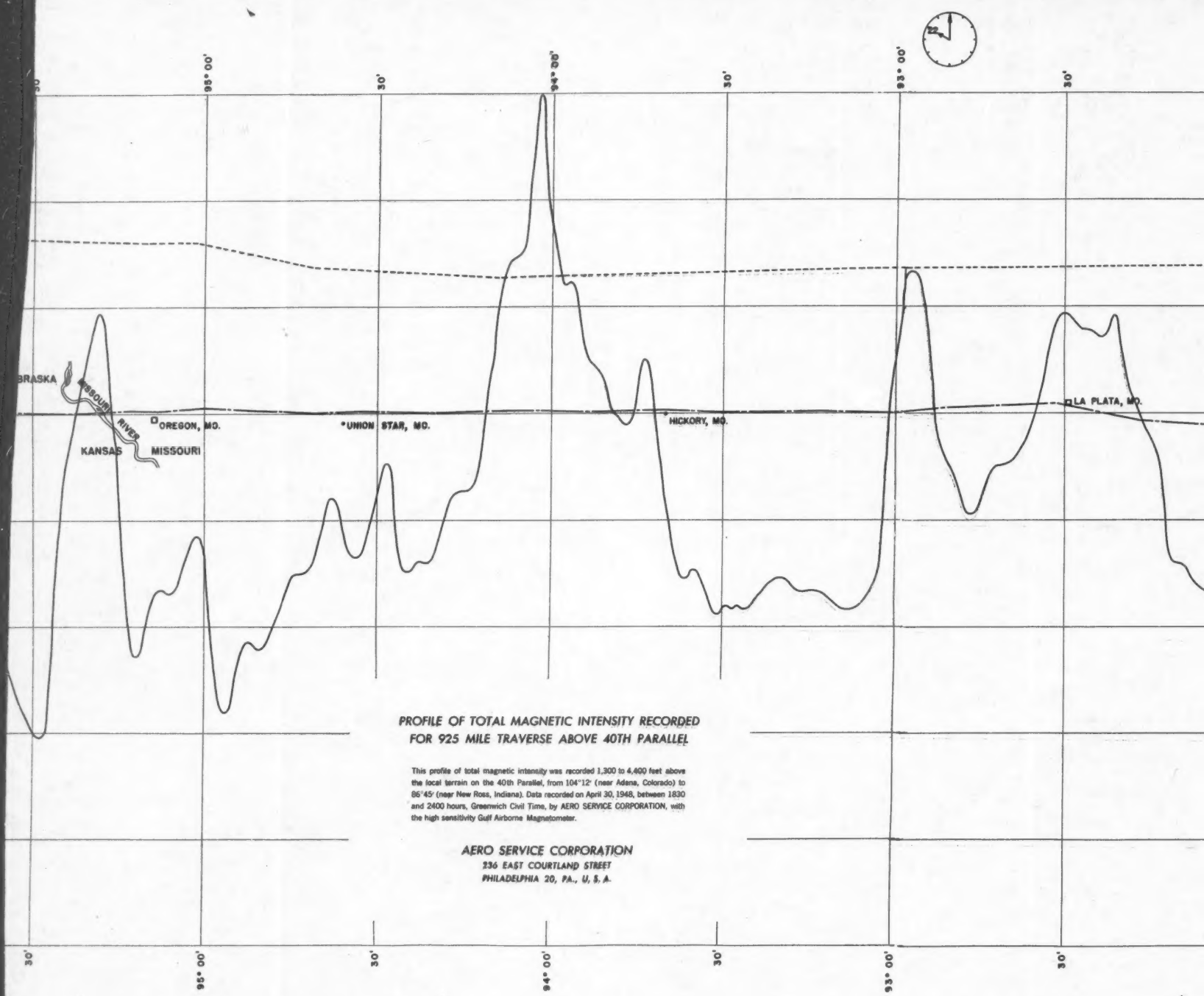


PROFILE OF TOTAL MAGNETIC INTENSITY RECORDED FOR 925 MILE TRAVERSE ABOVE 40TH PARALLEL

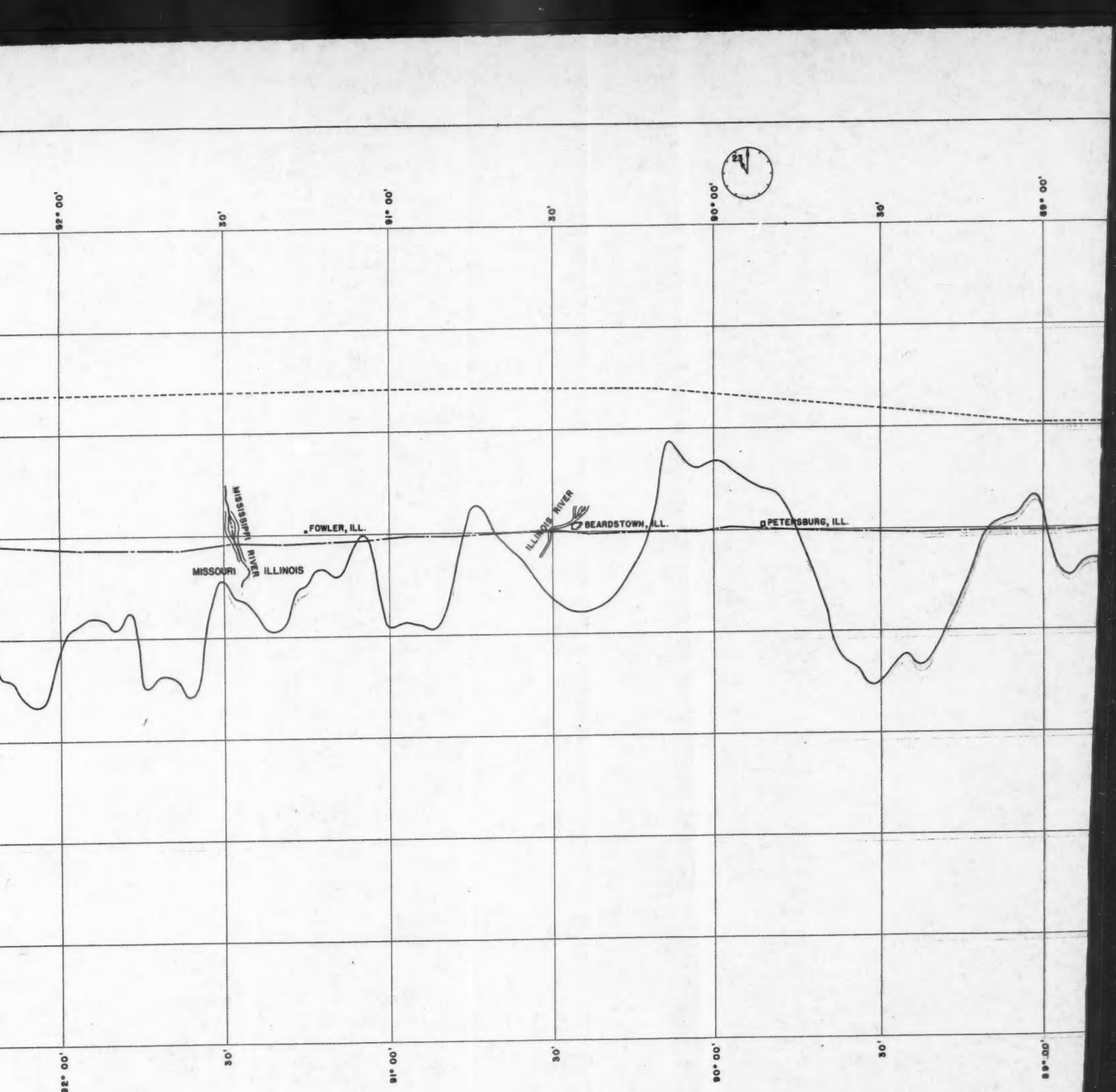
This profile of total magnetic intensity was recorded 1,300 to 4,400 feet above the local terrain on the 40th Parallel, from 104°12′ (near Adena, Colorado) to 86°45′ (near New Ross, Indiana). Data recorded on April 30, 1948, between 1830 and 2400 hours, Greenwich Civil Time, by AERO SERVICE CORPORATION, with the high sensitivity Gulf Airborne Magnetometer.

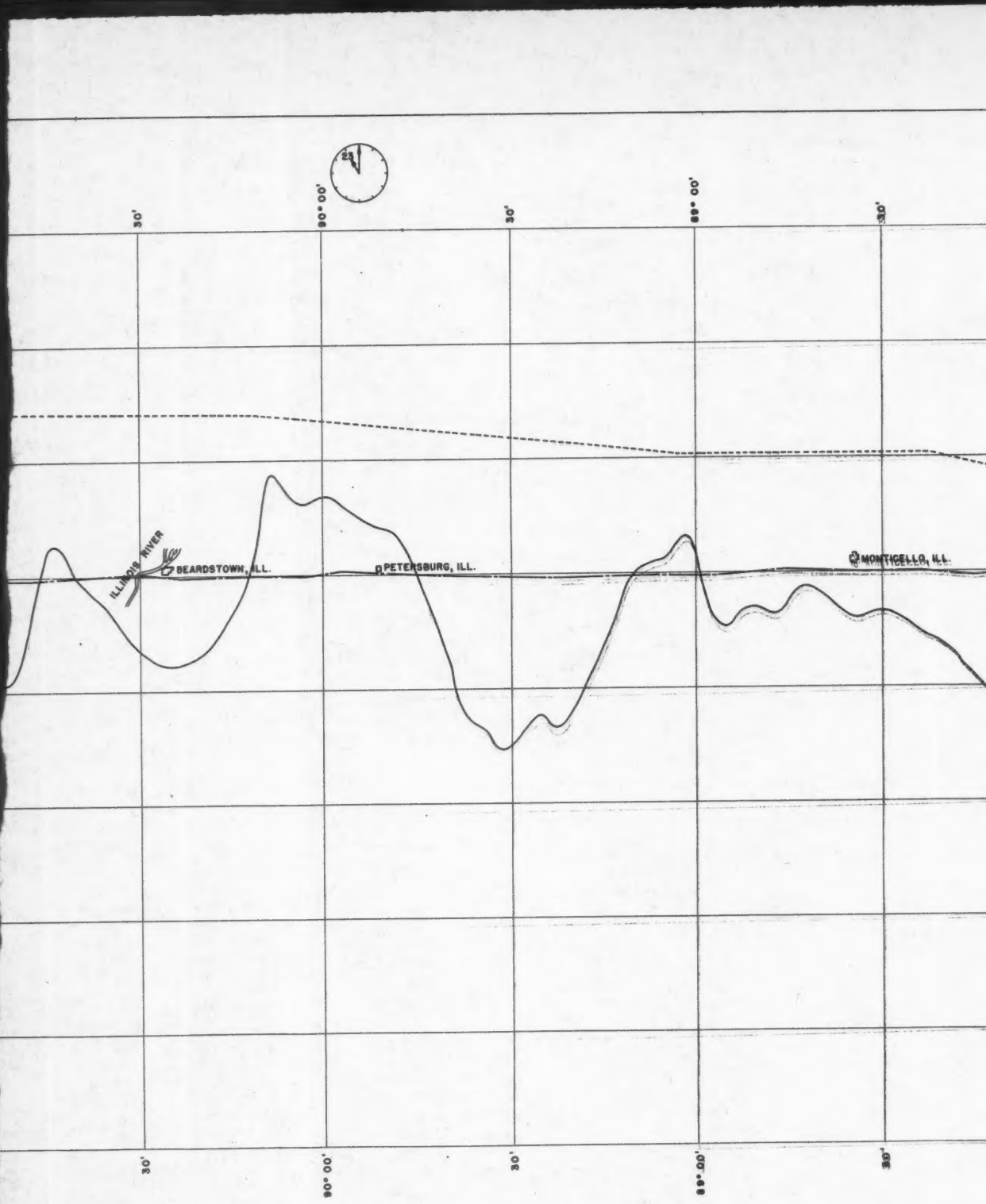
AERO SERVICE CORPORATION
236 EAST COURTLAND STREET
PHILADELPHIA 20, PA., U. S. A.

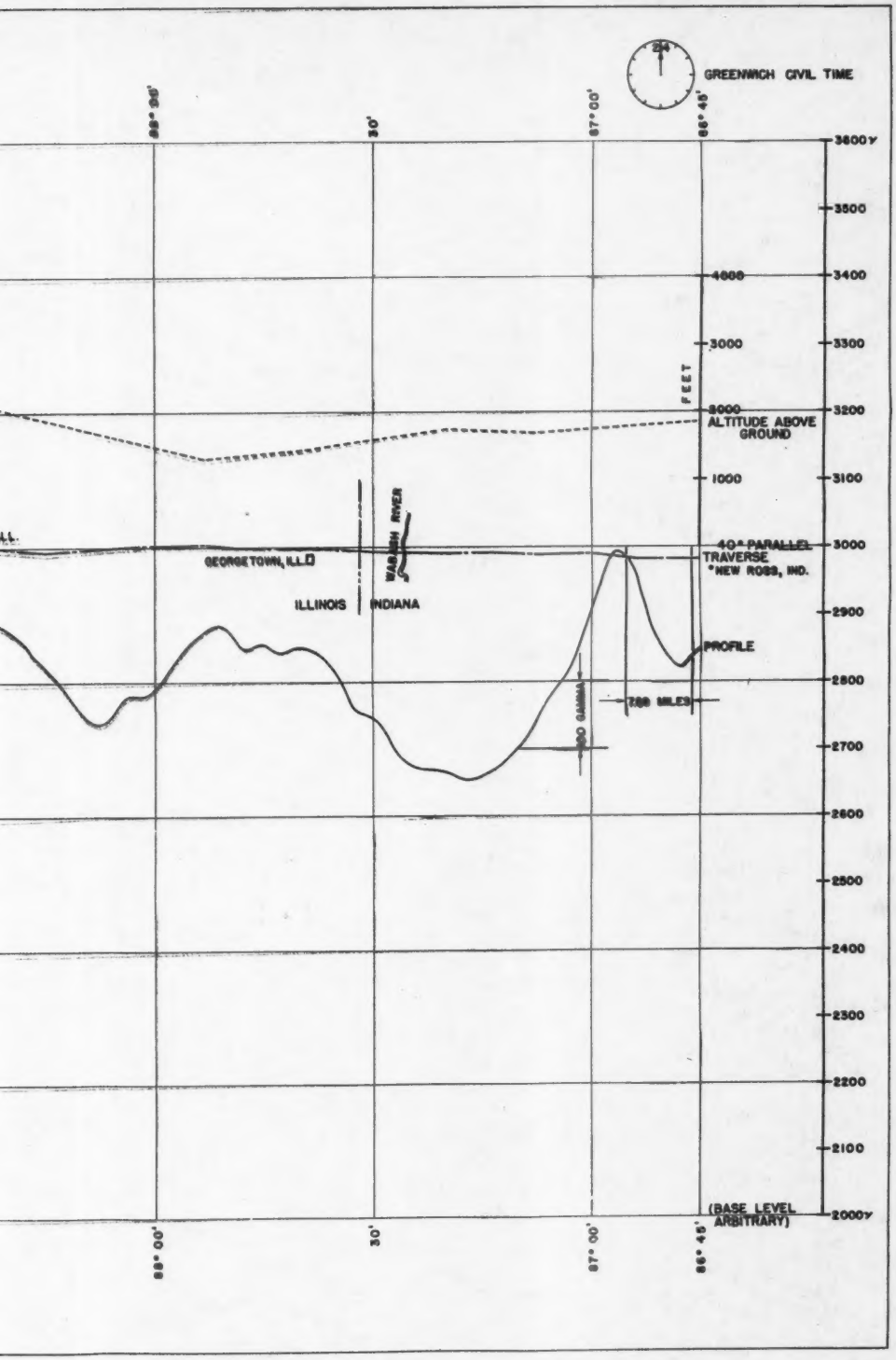
terrain on 40th parallel between longitude 104° 12′ (near Adena, Colorado) and 86° 45′ (near New Ross, Indiana).


95° 00'
30'
94° 00'
30'
93° 00'
30'
BRASKA
MISSOURI RIVER
KANSAS
MISSOURI
OREGON, MO.
UNION STAR, MO.
HICKORY, MO.
LA PLATA, MO.
PROFILE OF TOTAL MAGNETIC INTENSITY RECORDED
FOR 925 MILE TRAVERSE ABOVE 40TH PARALLEL
This profile of total magnetic intensity was recorded 1,300 to 4,400 feet above the local terrain on the 40th Parallel, from 104°12' (near Adena, Colorado) to 86°45' (near New Ross, Indiana). Data recorded on April 30, 1948, between 1830 and 2400 hours, Greenwich Civil Time, by AERO SERVICE CORPORATION, with the high sensitivity Gulf Airborne Magnetometer.
AERO SERVICE CORPORATION
236 EAST COURTLAND STREET
PHILADELPHIA 20, PA., U. S. A.

parallel between longitude 104° 12′ (near Adena, Colorado) and 86° 45′ (near New Ross, Indiana).


92° 00'
30'
91° 00'
30'
90° 00'
30'
89° 00'
MISSISSIPPI RIVER
MISSOURI
ILLINOIS
FOWLER, ILL.
ILLINOIS RIVER
BEARDSTOWN, ILL.
PETERSBURG, ILL.


30'
90° 00'
30'
89° 00'
30'
ILLINOIS RIVER
BEARDSTOWN, ILL.
PETERSBURG, ILL.
MONTICELLO, ILL.
30'
90° 00'
30'
89° 00'
30'


24
GREENWICH CIVIL TIME
88° 30'
30'
87° 00'
86° 45'
3600'
3500
4000
3400
3000
3300
FEET
2000
3200
ALTITUDE ABOVE GROUND
1000
3100
40° PARALLEL
3000
TRAVERSE
*NEW ROSS, IND.
GEORGETOWN, ILL.
WABASH RIVER
ILLINOIS
INDIANA
2900
PROFILE
2800
200 GAMMA
2700
2600
2500
2400
2300
2200
2100
(BASE LEVEL ARBITRARY)
2000'
88° 00'
30'
87° 00'
86° 45'

AIRBORNE MAGNETIC PROFILE ABOVE 40TH PARALLEL, EASTERN COLORADO TO WESTERN INDIANA*

HOMER JENSEN†

On the return trip from the Geophysical Meetings in Denver in the spring of 1948, the Gulf magnetometer in the Aero Service Corporation DC-3 magnetometer survey plane was operated continuously from a point near Adena, Colorado, to the vicinity of Indianapolis, Indiana, as part of a program of running long lines in the course of routine transfer of survey airplanes.

Ground position was established through the use of a continuous-strip camera, which gave an unbroken record of the path for the whole trip. The path was then reconstructed by establishing position on Geological Survey quadrangle sheets over those areas covered by the sheets and by correlation with other map sources at the western end of the run where quadrangle sheets were not available.

The altitude over a considerable part of the run was in excess of the scale of the recording radio-altimeter in the aircraft, so the altitude was established by subtracting the mean local ground height from the barometric altimeter record as corrected locally.

No correction is made for a diurnal variation nor for instrumental drift; but it was established at the end of the flight that the total instrument drift had been less than 50 gammas.

The frequency-response characteristics and the noise level of the record are such that the magnetic trace can be accepted as valid within the limits of the line width on the published curve. The datum level is arbitrary and is chosen merely for convenience. The survey was conducted in a manner to insure precise recording of the local variations in total magnetic intensity, rather than to establish exactly the relative values at the opposite ends of the traverse.

In this record, as in all high-sensitivity airborne-magnetometer records, the scalar value of total magnetic intensity, rather than any particular projection of the magnetic vector, is measured. Essentially, each local variation can be taken as the projection of the local anomalous vector upon the total-field vector.

This flight of more than 900 miles is well within the limits of routine survey operation with the airborne magnetometer. Day after day during the peak of the Bahamas survey, equivalent distances of Shoran-guided magnetometer traverse lines were flown; and in the Canadian bush, the Aero PBY survey plane has produced more than 1,000 miles of useable magnetometer traverse in a single day, hundreds of miles from the nearest base of supplies.

* Manuscript received by the Editor August 23, 1948.

† Aero Service Corp., Philadelphia, Pennsylvania.

INDEX OF WELLS SHOT FOR VELOCITY*
(Second Supplement)

B. G. SWAN†

ABSTRACT

This is the second supplement to the original Index published in the October 1944 issue of *Geophysics*, the first supplement appearing in the October 1946 issue. Information is listed on 239 velocity surveys, most of which were shot in the years 1946, 1947, and 1948. A considerable number of foreign wells are included. Corrections and information missing on some of the surveys of the original Index and the 1946 supplement are tabulated.

INTRODUCTION

This is the second supplement to the original "Index of Wells Shot For Velocity," published in the October 1944 issue of *Geophysics*. Information on the surveys was assembled by soliciting the various companies engaged in seismograph operations, and again the response was gratifying. This splendid cooperation indicates that the Index has proven of practical value to many geophysicists.

The first part of this supplement gives surveys shot since the 1946 supplement and other previously unreported wells. In the latter portion, shown in italics, corrections and additional information on previously listed surveys are given.

The lists received from various companies indicate considerable uncertainty as to the meaning of the "Shot by" column in the Index. The original intent was that this should be the name of the crew actually making the survey. In the case of a contracting company working for a client, the contracting company name should appear. Errors existing in this column are secondary, however, and have no real bearing on the usefulness of the Index. New abbreviations appearing in this column are: "R. R. I." for Rogers-Ray, Inc.; "G. G. C." for General Geophysical Company, and "S. G. C." for Southern Geophysical Company.

The writer is grateful to Miss Evelyn Lunn for her assistance in the necessary task of cross-checking and reconciling information from the various sources.

* Manuscript received by the Editor October 11, 1948. A limited number of reprints of this Index are available on request to the Business Manager.

† Continental Oil Co., Ponca City, Okla., serving as special editor to assemble and revise this Index.

INDEX OF WELLS SHOT FOR VELOCITY

STATE OF ALABAMA

County	*Company*	*Lease*	*Location*	*Depth*	*Shot by*	*Date*	*Sponsored by*
Crenshaw	Nelson Explor. Co.	No. 1 Smith Lumber Co.	C SW NE NW 26, 8N-16E	9,000	K.V.I.	1947	Atlantic
Geneva	Shell	No. 1 Free	5, 2N-19E	3,580	Shell	1946	———
Mobile	E. B. Sullivan	No. 1 Thompson	SE NE 31, 2N-2W	8,975	Humble	1948	Humble

STATE OF ARKANSAS

Bradley	Marine Oil Co.	No. 1 Crawford	17, 12S-9W	4,503	Carter	1947	Carter
Desha	Carter	No. 1 Isom	C SE SW 33, 9S-1W	4,725	Carter	1947	Carter
Lafayette	Barnsdall-Spartan	No. 1 Bodcaw Lumber Co.	SE SW 8, 18S-23W	9,707	NGC	1947	Barnsdall et al.

STATE OF CALIFORNIA

Colusa	Standard	No. 1 Williams Comm.	33, 15N- 2W	3,119	Amerada	1947	CWVSG
Kern	General Pet.	No. 1 B. M. Q.	20, 11N-23W	4,530	WGC	1946	CWVSG
Kern	Western Gulf	No. 1 S. P.	25, 12N-20W	9,997	Gulf	1947	CWVSG
Kern	Shell	No. 1 Guth-McCaleb Comm.	12, 26S-26E	5,269	Shell	1947	CWVSG
Kern	Richfield	No. 1 Berry	30, 28S-21E	8,400	Texaco	1947	CWVSG
Kern	Shell	No. 53-30 K. C. L.-A.	30, 30S-26E	12,100	Shell	1947	CWVSG
Kern	Texas Co.	No. 28-28 Tulare N. T. C.	28, 30S-22E	6,150	Texaco	1947	CWVSG
Kern	Richfield	No. 1 Buck	6, 27S-21E	7,716	GSI	1947	CWVSG
Kern	Western Gulf	No. 1 Crown Zellerbach	27, 25S-24E	4,000	GSI	1947	CWVSG
Kern	General Pet.	No. 32 Glazier	2, 30S-29E	5,770	WGC	1947	CWVSG
Kern	G. P. Cottonwood	No. 22-30 Socal	30, 29S-30E	4,250	GSI	1948	CWVSG
Kern	R. B. Jackson	No. 1	28, 27S-27E	3,900	GSI	1948	CWVSG
Kern	St. Anthony Oil	No. 1	18, 28S-28E	5,600	GSI	1948	CWVSG
Kern	Richfield	No. 1 K. C. L.-Old River	3, 31S-26E	9,150	GSI	1944	CWVSG
Kings	Standard	No. 2 Discombe	1, 24S-22E	3,360	GSI	1947	CWVSG
Los Angeles	Standard	No. 2-1 Stern	7, 3S-10W	11,700	UGC	1946	CWVSG
Los Angeles	Standard	No. 1 Newsom Comm.	36, 2S-12W	9,865	WGC	1947	CWVSG
Orange	Bandini Pet.	No. 1 Segerstrom	34, 5S-10W	6,930	UGC	1947	CWVSG
Orange	Shell	No. 51-6 Lamb	6, 6S-10W	7,810	Amerada	1948	CWVSG
Solono	Shell	No. 1 Dozier-Pressley	16, 3N-2E	6,450	Shell	1946	CWVSG
Tulare	Pacific Western	No. B-1 Brunner	16, 24S-25W	—	WGC	1947	CWVSG
Ventura	Standard	No. 2 McGrath	26, 2N-23W	11,470	GSI	1947	CWVSG
Yolo	Shell	No. 1-1 Meridian U	5, 9N-1E	5,100	Shell	1947	CWVSG
Yolo	Shell	No. 1-1 Pleasant Creek Unit	22, 8N-1W	6,200	Shell	1948	CWVSG
Yolo	Shell	No 2-1 Winters Unit	18, 8N-1E	8,450	Shell	1947	CWVSG

STATE OF COLORADO

Baca	California Co.	No. 1 Spikes	C SW NE 13, 31S-48W	6,239	KVI	1947	KVI
Baca	Sharpless Corp.	No. 1 L. Murray	SW SW SE 26, 29S-50W	5,554	KVI	1946	KVI
Moffat	Carter	No. 1 North Craig	SE SE 30, 8N-90W	8,990	Carter	1947	Carter
Moffat	Cities Service et al.	No. 1 Government	27, 12N-96W	5,461	———	1947	RMSWSA
Prowers	California Co.	No. 1 Luster	C NE SE 10, 22S-47W	5,501	KVI	1946	KVI

STATE OF FLORIDA

Bay	Pure Oil	No. 4 International Paper	Sec. 8, 3S-12W	4,940	Shell	1946	Shell
Clay	Humble	No. 1 Foremost	NW/4 4, 6S-25E	5,850	Humble	1947	Humble
Hernando	Ohio	No. 1 Hernasco Corp.	NW/4 19, 23S-18E	8,400	Humble	1946	Humble
Highlands	Humble	No. 1 Carlton	SW/4 34, 38S-29E	12,655	Humble	1946	Humble
Hillsborough	Humble	No. 1 Jamerson	NE/4 7, 31S-22E	10,035	Humble	1946	Humble
Walton	Logan, Trustee	No. 1 Walton L & T Co.	C SW SW 14, 1N-18W	6,000	Shell	1946	Shell

County	Company	Lease	Location	Depth	Shot by	Date	Sponsored by
			STATE OF GEORGIA				
Clinch	Sun	No. 1 Barlow	Land lot #1, 12th Dist.	3,755	WGC	1947	California
			STATE OF ILLINOIS				
Marion	Shell	No. 6C Ververs	Sec. 18, 3N-1E	4,080	Shell	1940	——
			STATE OF KANSAS				
Meade	Helmerich-Payne	No. 1 R. E. Adams	SW NW 11, 35S-29W	6,150	Gulf	1946	OKWSA
			STATE OF KENTUCKY				
Rowan	Ashland	No. 1 Caudill	U-74, Sec. 20	3,360	WGC	1947	California
			STATE OF LOUISIANA				
Cameron	Magnolia	No. 1-C Lutcher Moore	Sec. 24, 14S-11W	11,600	KVI	1947	KVI
Cameron	Magnolia	No. 1-3 Lutcher	Sec. 24, 14S-11W	11,451	IXC	1948	Magnolia
Rapids	Burton	No. 1 Bentley Lumber Co.	NE/4 NW/4 33, 5N-5W	10,819	Gulf	1947	Gulf
Richland	Murphy-Sun	No. 1 Thorpe	SE NE 22, 17N-9E	4,321	Petty	1946	Sun
Plaquemines	Texas Co.	No. 1 Bradish-Johnson	C SW NE 19, 18S-26E	12,976	Texaco	1947	Texaco
St. James	Shell	No. 1 Colonial Sugars	Sec. 5, 12S-5E	7,490	Shell	1936	Shell
St. James	Shell	No. 1 Lebermuth & Israel Pt. Co.	Sec. 39, 12S-15E	10,480	Shell	1939	Shell
Terrebonne	Magnolia	No. 1 La. Gulf Blk. 58	Blk. 58, Eugene Is. Area Gulf of Mex., Mag. Lse. #673	12,878	Magnolia	1947	Magnolia
			STATE OF MICHIGAN				
Tuscola	Shell	No. 1 Hutchinson	Sec. 21, 14N-11E	3,733	Shell	1945	——
Tuscola	Shell	No. 1 Woidan	Sec. 16, 13N-11E	4,185	Shell	1945	——
			STATE OF MISSISSIPPI				
Adams	Sinclair	No. 1 DeMarco	Sec. 14, 6N-2W	10,750	Sohio	1947	Sohio
Amite	Gulf	No. 1 Rowland Trustees et al. "A"	Sec. 39, 4N-2E	11,513	Gulf	1947	Gulf
Attala	Shell	No. 1 Wheless	Sec. 5, 14N-9E	6,200	Shell	1945	Shell
Attala	Gulf	No. 1 Peeler	Sec. 35, 15N-9E	4,199	Gulf	1940	Gulf
Issaquena	Burns & Miller	No. 1 Mohanna	Sec. 11, 18N-3E	6,950	GRC	1946	GRC
Jones	Gulf	No. 1 Majors	NE/4 29, 6N-11W	12,903	Gulf	1947	Gulf
Lamar	Amerada	No. 1 Vesely	SW NE 7, 4N-15W	9,350	GRC	1946	GRC
Madison	Carter	No. 1 Billingslea	C NE SW 30, 11N-4E	6,630	Carter	1943	Carter
Neshoba	Slick-Plains	No. 1 Breazeale	SW SE 28, 12N-10E	6,110	Shell	1947	Shell
Smith	Woodley Pet.	No. 1 Womack Butler Unit	Sec. 36, 1N-6E	9,503	Shell	1947	Shell
Stone	R. W. Norton	No. 5 Dantzler Lbr. Co.	C NW NW 2, 4S-11W	11,504	Atlantic	1947	Atlantic
				deepened to 13,800	Atlantic	1948	Atlantic
Warren	Amerada	No. 1 Dabney-Bonelli	Sec. 9, 18N-2E	5,150	GRC	1947	GRC
Washington	Murphy-Sun	No. 1 Brown	NW SE 19, 16N-7W	5,077	Petty	1946	Murphy-Sun
			STATE OF MONTANA				
Liberty	Texas Co	No. 2 Nick Laas	14, 33N-4E	4,564	Texaco	1946	Texaco
Phillips	Texas Co.	No. 1 Bowdoin Unit 822	C SW SW 8, 32N-32E	5,803	Texaco	1947	Texaco
			STATE OF NEW MEXICO				
			31, 3N-28E	6,356	Geotech.	1946	Pure
DeBaca	Pure	No. 1 Pure (Fee)	SW SW NE 23, 20S-37E	10,153	KBI	1947	KVI
Lea	Continental et al.	No. 5 Skaggs B-23	NE NE 28, 23S-37E	10,208	KVI	1948	Gulf
Lea	Gulf	No. 6 La Munyon	C SE NE 25, 19S-35E	8,900	GRC	1947	GRC
Lea	Amerada	No. 2 Record		13,520	KVI	1948	Amerada
		No. 2 Record (Deepened)	1, 20S-36E	7,650	GRC	1947	GRC
Lea	Amerada	No. 5 Phillips	SW SE 27, 9S-36E	11,612	Magnolia	1948	Magnolia
Lea	Mid-Continent	No. 1-A Sawyer					

STATE OF OKLAHOMA

County	Company	Lease	Location	Depth	Shot by	Date	Sponsored by
Beaver	Gulf	No. 1 Ratzlaff	SE SE NW 9, 3N-21ECM	8,848	Gulf	1946	Gulf
Beaver	Gulf	No. 1 Lloyd	SE NW NW 31, 4N-21ECM	2,695	Gulf	1946	Gulf
Beaver	Gulf	No. 1 Stickler	C SE SE NW 5, 3N-21ECM	2,493	Gulf	1947	Gulf
Beaver	Gulf	No. 1 Mendenhall	C SE SE SW 21, 4N-20ECM	2,666	Gulf	1947	Gulf
Beaver	Gulf	No. 1 Boileau	C SE SE SW 27, 3N-20ECM	2,659	Gulf	1947	Gulf
Beaver	Gulf	No. 1 Seal	C SW SW SW 34, 3N-23ECM	2,662	Gulf	1947	Gulf
Beaver	Gulf	No. 1 Venable	C SW SW SW 32, 3N-23ECM	3,093	Gulf	1947	Gulf
Beaver	Gulf	No. 1 McNew	C SE SE SE 28 5 N-20ECM	2,665	Gulf	1947	Gulf
Caddo	Texas Co.	No. 1 Smith	2, 5N-12W	4,278	Texaco	1940	Texaco
Canadian	Sohio	No. 1 Specht	C SE NE 36, 14N-5W	—	N.Am.G.C.	1944?	Sohio
Carter	Amerada	No. 1 Smalley	19, 4S-3W	6,850	GRC	1947	GRC
Cimarron	Texas Co.	No. 1 Hall	C NE SW 29, 2N-3E	6,750	Texaco	1947	Texaco
Dewey	Magnolia	No. 1 Winters	C SW NE 9, 19N-20W	13,216	KVI	1947	KVI
Dewey	Oklahoma Natural	No. 1 Green (Oakwood Unit)	NW NW NW 6, 17N-14W	12,603	Carter	1946	OKWSA
Garvin	Carter	No. 2 Bohanon	NW SW NE 14, 2N-2W	7,936	Carter	1947	KVI
Garvin	Sohio	No. 1 Kennedy	NW NW SE 26, 1N-2W	8,598	SSC	1947	KVI
Garvin	Sohio	No. 1 Howard	SE SE NW 17, 1N-2W	10,035	Century	1947	KVI
Grady	Stanolind	No. 1 Briscoe Unit	C NW SE 4, 4N-5W	13,800	Stanolind	1948	OKWSA
Grant	Sunray	No. 1 Kent	C NE NE 21, 26N-8W	6,100	KVI	1947	KVI
Jefferson	Phillips	No. 1 Price	C NE SE 21, 3S-7W	7,085	SSC	1948	Phillips
Noble	Gulf-Mazda	No. 1 Bettie Hon	NE NE SW 34, 24N-1E	4,802	KVI	1947	KVI
Oklahoma	Mid-Kansas Oil & Gas	No. 1 Dahl	31, 14N-3E	6,220	Petty	1934	———
Oklahoma	L. S. Youngblood	No. 1 Swatek	C NW SW 7, 11N-4W	8,630	N.Am.G.C.	1943	Sohio
Pottawatomie	Macmillan Pet. Co.	No. 1 Steele et al.	SW NW SE 5, 11N-3E	5,777	Ok. S. Co.	1948	Ok. S. Co.
Pottawatomie	Alma Oil	No. 1 Harrington	24, 9N-4E	—	———	1940	———
Seminole	W. J. Sherry	No. 1 Butner	SW SE SE 9, 9N-8E	3,618	SSC	1947	Sherry
Stephens	Coline Oil Corp.	No. 1 Cooper-Johnson	SE NW SE 1, 2N-8W	12,110	KVI	1946	KVI
Stephens	Gulf	No. 1 March	C NW NW 25, 2N-8W	7,882	KVI	1947	KVI
Stephens	Atlantic	No. 8 Taylor	SW SW NW 12, 1S-4W	5,140	KVI	1948	KVI
Stephens	Amerada	No. 11 Sledge	19, 1S-5W	9,149	GRC	1948	GRC
Stephens	Amerada	No. 1 Rowland	30, 1S-5W	9,548	GRC	1948	GRC

STATE OF TEXAS

District: East							
Cass	Shell	No. 1 Smith	R. Peters Survey, A-831	10,790	Petty	1948	Shell
Cherokee	Standard of Texas	No. 1 New Birmingham Dev.	G. E. Looney Survey	9,550	WGC	1947	Standard
Kaufman	Shell	No. 1 Lumpkin	B. S. Newman Sur., A-363	10,785	Petty	1948	Shell
Wood	Shell	No. 12 Goldsmith	E. Goodsir Survey	11,150	SGC	1947	Shell
District: Gulf Coast & South							
Brazoria	Holmes Drlg. Co.	No. 1 Turner	S. F. Austin Sur., A-25	9,393	Shell	1948	SSWSA
Frio	Magnolia	No. 1 McKinley	M. C. Davidson Survey	11,951	Magnolia	1947	Magnolia
Houston	Ivy-Moran	No. 3 Murray & Sons	John Durst Survey	9,550	Atlantic	1946	Atlantic
Lee	Standard of Texas	No. 1 Biggers	Marshall Sur., A-212	7,325	WGC	1948	Stan. of T.
Matagorda	Sun-Skelly	No. 1 Gregg Laurence	Amos Rawls Survey A-81	11,950	GGC	1948	Skelly
McMullen	Gulf	No. 1-D Shiner Ranch	Alderete Sur. #14, A-842	8,988	Petty	1948	Shell
San Patrico	Smith-Auld et al.	No. 1 Serviere	G. T. Tabor Sur., A-165	11,024	Petty	1946	Atlantic
Starr	Sun	No. 2-A Lopez	Santa Cruz F. F. Grant	10,490	Shell	1948	SSWSA
Trinity	Humble	No. 1 Thompson Bros.	John Chamblis Survey	11,900	Humble	1948	SSWSA
Victoria	Wellington Oil Co.	No. 1 Booth	Ind. R.R. Co. A-440	8,750	Texaco	1940	Texaco
Willacy	Texas	No. 6 Uturria	Share 3 C. Grant Survey	15,900	Texaco	1947	Texaco

County	Company	Lease	Location	Depth	Shot by	Date	Sponsored by
District: North							
Archer	Kadane-Griffith	No. 1-D Frey	Sec. 10, Palo Pinto CSL	4,526	NGC	1947	Kad.-Grif.
Clay	Continental	No. 1 Scott	Blk. 3239, T.E. & L. Sur.	6,247	KVI	1946	KVI
Grayson	Standard of Texas	No. 1 Mitchell	McNair Survey, A-763	11,500	GSI	1946	Stan. of T.
Grayson	Standard of Texas	No. 1 Rifenburg	John Jennings Sur., A-647	4,859	GSI	1947	Stan. of T.
Grayson	Standard of Texas	No. 1 Stout	B. J. Hutson Survey	4,980	GSI	1948	Stan. of T.
Jones	B. J. Wynne, Trustee	No. 1 Beaty & Akin	Sec. 44, D&D Asylum	5,230	GSI	1947	Pan-Am.
Jones	West Central Drlg.	No. 7-A Wimberly	NW 87, Blk. 126, DeWitt CSL	5,642	JVI	1947	KVI
Montague	Magnolia	No. 1 Stowe	S. Stowe 84.67A	5,653	GSI	1946	Magnolia
Shackelford	Big West Drlg. Co.	No. 1 Hendrick 12A	Sec. 8, Blk. A, AB&M Sur.	5,257	KVI	1947	KVI
Shackelford	Humble	No. 1 Green	Sec. 1548, TE&L Co. Sur.	4,500	Humble	1947	Humble
Stephens	Texas Pacific	No. 2 Peeks	Sec. 2261, TE&L Co. Sur.	4,250	IXC	1947	Tex-Pac.
Throckmorton	Woodley Pet. et al.	No. 1 Odell	Sec. 695, TE&L Co. Sur.	4,917	KVI	1947	KVI
Young	Kerlyn	No. 1 Morrison	S. Davidson Sur., A-84	4,243	Shell	1943	———
District: Panhandle							
Castro	Sun	No. 1 Herring	Blk. T-4, Thomson Survey	10,224	Sun	1948	Sun
Roberts	Phillips	No. 1 Jenkie	Blk. 2, I&GNRR Survey	8,950	SSC	1947	Phillips
District: West							
Andrews	Globe Oil & Ref.	No. 1-A Lockhart & Brown	NE Cor. 20 Blk. A-41 PSL	8,680	KVI	1946	KVI
Andrews	Richmond Drlg.	No. 1 Bryant-Link	Sec. 7, Blk. A-48	4,900	Shell	1939	Shell
Andrews	Shell	No. 1 Pinson	Sec. 13, Blk. A-40, PSL Sur.	10,780	UGC	1946	SSWSA
Borden	Tidewater	No. 1 Clayton & Johnson	Sec. 47, T&P Blk. 31, 4N	9,077	Gulf	1948	Gulf?
Cochran	Stanolind	No. 1 Hall	Sec. 13, Blk. L. PSL Sur.	11,065	Stanolind	1947	Stanolind
Coke	Sun	No. 1 Tubb	Sec. 253½ B. L. Anthony Sur.	6,476	KVI	1947	KVI
Coke	Union of Calif.	No. 1 McCutchen	Sec. 444, Blk. 1-A, H&TC Sur.	6,740	WGC	1947	———
Crane	Gulf	No. 3 McKnight	Sec. 9, Blk. B-21	6,427	Gulf	1938	Gulf
Crane	Byrd & Forst	No. 1 Eppenauer	Sec. 20, H&TC Blk. #6	5,984	Gulf	1947	Gulf
Crane	Gulf	No. 1 H. H. University	Sec. 3, Univ. Blk. 31	10,704	Gulf	1947	Gulf
Crane	Gulf	No. 1 Barnsley	Sec. 41, PSL Blk. 32	8,542	Gulf	1947	Gulf
Crane	Gulf	No. 7-E Wristen Bros.	Sec. 17, PSL Blk. B-28	8,133	Gulf	1947	Gulf
Crane	Gulf	No. 1-A Connell	Sec. 26, PSL Blk. 22	9,685	Gulf	1947	Gulf
Crockett	Loffland Bros.	No. 1 Cox	Sec. 40, Blk. "ST" TCR Sur.	10,910	Gulf	1946	Gulf
Crockett	Stanolind	No. 1-GG University	Sec. 12, Blk. 30, Univ. Lds.	8,200	Stanolind	1946	Stanolind
Crockett	Ted Weiner	No. 1 Vaughn	Sec. 86, Blk. OP-GC&SFRR Sur.	7,700	Gulf	1947	Gulf
Crockett	Moncrief-Hyde	No. 1 Helbing	Sec. 16, Blk. QRGC&SFRR Sur.	8,990	Texaco	1947	Texaco
Crockett	Sinclair & Atlantic	No. 1-66 University	Sec. 30, Blk. 46, Univ. Lds.	7,660	Petty	1947	SSWSA
Crockett	Texas Co.	No. 1-U State of Texas	Sec. 22, Blk. 40 Univ. Lds.	8,660	Texaco	1948	Texaco
Crockett	Texas Co.	No. 1 Pierce	Sec. 5, Blk. O, C. W. Brown	11,641	Texaco	1948	Texaco
Crockett	Amerada	No. CTA Amerada Univ.	Sec. 23, Blk. 42	8,680	GRC	1947	GRC
Crosby	Ohio Oil Co.	No. 1 Jones	Sec. 140, Blk. 2, H&GNRR Co.	8,626	GGC	1948	Ohio
Dawson	Seaboard Oil	No. 6 Robinson	Sec. 37, T&PRR Blk. 34, 5N	11,097	Gulf	1947	Gulf
Ector	Gulf	No. 1 Fogelson Univ.	Sec. 7, Univ. Blk. 35	8,914	Gulf	1947	Gulf
Ector	Gulf	No. 421 Goldsmith	Sec. 15, Blk 44, 1S	9,672	Gulf	1947	Gulf
Ector	Stanolind	No. 1 Kayser	Sec. 34, Blk. 43, 2S, T&P	13,430	Texaco	1946	Texaco
Ector	Texas Co.	No. 29 Connell	Sec. 9, Blk. B-16, PSL	9,650	Texaco	1946	Texaco
Fisher	Danciger	No. 1 Cochran	Sec 31, Blk. 3, H&TCRR	7,017	SSC	1948	Danciger
Garza	Union & Cities Ser.	No. 1-A Davies	Sec. 7, Blk. 4, Aycock Sur.	8,725	WGC	1948	Union
Hale	Standard of Texas	No. 1 Keliehor	Lge. 3, Callahan Co. Sch. Lds.	7,500	SGC	1948	Stan. of T.
Hockley	Gulf	No. 23 Mallet	Sec. 2, PSL, Blk. "X"	4,200	Gulf	1945	Gulf
Irion	Skelly	No. 1 Sugg	Sec. 45, Blk. 1, H&TC Sur.	8,700	Atlantic	1945	Atlantic
Mitchell	Fullerton-Phillips	No. 1 Strain	Lot 10, C. A. O'Keffe Sur.	7,863	SGC	1948	Stan. of T.
Pecos	Helmerich & Payne	No. C-9 White & Baker	Sec. 44, Blk. Z, TCRR Sur.	10,030	KVI	1946	KVI
Reagan	Gulf	No. 1 Hughes	Sec. 8, TCRR Sur., Blk. L.	10,700	Gulf	1947	Gulf
Reagan	Superior Oil	No. B-1-A University	Sec. 12, NE Blk. 1, Univ. Lds.	10,250	IEC	1945	Superior
Reeves	Argo Oil Co.	No. 1 Roberts	Sec. 294, Blk. 13, H&GNRR	7,840	NGC	1946	SSWSA
Runnels	Standard of Texas	No. 1 Lilly et al.	Burnet Sch. Lds. Sur. 271	5,440	GSI	1948	Stan. of T.

County	*Company*	*Lease*	*Location*	*Depth*	*Shot by*	*Date*	*Sponsored*
Schleicher	Sinclair-Prairie	No. 1 McClatchy	Sec. 41, Blk. M, GH&SARR	7,345	Petty	1948	Sinclair
Scurry	Ohio Oil Co.	No. 1-C Neal Estate	Miller Survey #1, A-68	7,286	GGC	1947	Ohio
Stonewall	Shell	No. 1 Rutherford	Sec. 144, Blk. 1 H&TC Sur.	6,192	Shell	1941	Shell
Stonewall	Shell	No. A-1 Patterson	Sec. 357, Blk. D, H&TC Sur.	6,775	Shell	1941	Shell
Stonewall	Pan American	No. 1 Jean	Sec. 166, H&TCCRR	6,341?	GSI	1947	Pan-Am.
Sutton	Humble	No. 2 Mayer	Sec. 40, Blk E. F., GC&SFRR	9,800	Shell	1948	Shell
Tom Green	Cities Service	No. 1 Jones	M. J. Fernandez Sur. #100	6,935	GGC	1948	Cities Ser.
Ward	Chizum et al.	No. 1 University	Sec. 27, Univ. Blk. 18	5,345	Texaco	1946	Texaco
Winkler	Hunt Oil Co.	No. 1 Hill	Sec. 9, PSL, Blk. 11	8,797	Gulf	1946	Hunt?
Winkler	Santa Fe	No. 1 Wheeler	Sec. 21, PSL, Blk. B-6	11,800	Gulf	1947	Gulf
Winkler	Carter	No. 1 Weight	Sec. 29, PSL, Blk. 40	12,374	Gulf	1947	Gulf
Winkler	Stanolind et al.	No. 35-A Hendrick T-88-M	Sec. 33, Blk. 26	13,385	SGC	1946	Atlantic
Yoakum	Drilling & Explor.	No. 1-D Davis	Blk. D, Gibson Survey	10,774	Geotech.	1946	Pure
			STATE OF UTAH				
Uintah	Carter	No. 1 Edna Davis	NW NW 33, 4S-20E	8,000	Carter	1947	Carter
			STATE OF WYOMING				
Campbell	Texas	No. 1 Adon Unit	Sec. 2, T 52 N-R72 W	9,935	UGC	1947	RMSWSA
Carbon	Texas Co.	No. 1 Unit	NE SE SE 35, 13N-92W	7,440	Western	1947	RMSWSA
Fremont	General Pet.	No. 45-25-G Antelope	NE NE SW 25, 27N-94W	10,050	Petty	1947	RMSWSA
Fremont	Texas	No. 1 Alkali Butte	Sec. 1, 35N-95W	6,570	Texaco	1947	Texaco
Hot Springs	Pioneer Oil Corp.	No. 1 OPC	C SW SE 12, 45N-97W	6,995	Republic	1948	Pioneer
Lincoln	Union	No. 1 Government	Sec. 30, 20N-115W	6,100	Stanolind	1948	RMSWSA
Niobrara	Shell	No. 1 Government	NE NE 29, 35N-65W	5,153	UGC	1947	RMSWSA
Sublette	Western Oil	No. 1-5 Unit (Pfoff)	Sec. 5, 27N-113W	2,365	Gen. Pet.	1947	Gen. Pet.
Sweetwater	Carter	No. 1 Great Divide	NE NE 13, 26N-93W	7,480	Carter	1947	Carter
Washakie	General Pet.	No. 88-24-G South Fork	Sec. 24, 46 N 92W	10,340	WGC	1947	RMSWSA
			FOREIGN COUNTRIES				
			CANADA				
Alberta	Gulf	No. 1 Pincher Creek	Sec. 24, T3-R29W, 4th	11,700	Can. Gulf	1948	Can. Gulf
Alberta	Co-op	No. 1 Stinsom Creek	Lsd. 11, Sec. 22, T17-R2W, 5th	10,608	Can. Expl.	1946	?
Alberta	Gulf	No. 1 Jerard	Lsd. 16, Sec. 34, T37-R20W, 4th	5,862	Gulf	1948	Can. Gulf
Alberta	Br. Amer. Omnitrans	No. 1 Hand Hills	Sec. 14, T30-R17W, 4th	6,500	GSI	—	———
Alberta	Imperial	No. 1 Morinville	Lsd. 9, Sec. 30, T56-R24W, 4th	4,980	Imperial	1947	Imperial
Alberta	Imperial	No. 1 Looma	Lsd. 4, Sec. 10, T50-R23W, 4th	6,502	Imperial	1947	Imperial
Alberta	McColl-Frontenac	No. 3-22-46-23-C	Lsd. 3, Sec. 22, T46-R23W, 4th	5,356	Imperial	1947	?
Alberta	McColl-Frontenac	No. 1 Wetaskiwin	Lsd. 4, Sec. 11, T45-R25W, 4th	6,500	Imperial-Heiland-Carter	1947	McColl-Front
Alberta	Anglo-Canadian	No. 2 Beaverhill Lake	Lsd. 11, Sec. 11, T50-R17W, 4th	5,157	Imperial	1947	?
Alberta	McColl-Frontenac	No. 1 Wizard Lake	Lsd. 14, Sec. 14, T48-R27W, 4th	6,229	Imperial	1947	McColl-Front
Alberta	Gulf	No. 1 Stony Plain	Sec. 9, T52-R26W, 4th	4,467	Can. Gulf	1947	Can. Gulf
Alberta	Marine Oil Co.	No. 1 Alice M. O'Brien	Lsd. 4, Sec. 12, T59-R3W, 5th	5,655	Can. Gulf	1948	Can. Gulf
Alberta	Imperial	No. 1 Paddle River	Sec. 17, T56-R8W, 5th	8,485	Imperial	1947	Imperial
Alberta	Imperial	No. 1 Leduc	Lsd. 5, Sec. 22, T50-R26W, 4th	4,437	Carter & Imperial	1947	Imperial
Alberta	Gulf	No. 1 Louis Warren	Lsd. 2, Sec. 11, T37-R23W, 4th	7,194	Gulf	1948	Gulf
Alberta	Toronto Syndicate	No. 1	Lsd. 1, Sec. 6, T22-R13W, 4th	4,177	Sun	1945	Sun
Alberta	Shell Oil	No. 5-7-1 Jumping Pound	Cochrane Area	14,439	Imperial	1947	Imperial
Alberta	Anglo-Imperial	No. 1 Crossfield	Lsd. 9, Sec. 11, T28-R2W, 5th	8,192	Carter	1946	Carter

County	Company	Lease	Location	Depth	Shot by	Date	Sponsored by
			COLOMBIA, SOUTH AMERICA				
Antioquia	Colombian Gulf	No. 3 Sardinata	N759,888.35, W3,355.37 Bogota Coord.	5,850	SSC	1947	Colom.-Gulf
			CUBA				
Pinar del Rio Province	Standard Oil of Cuba	No. 1 Baños	3 mi. W. of town of Los Palacios	6,700	IPC	1946	Stan. Oil of Cuba
			DENMARK				
	Danish-American Prospecting Co.	No 4 Suldrup	56°52.18′N of equator 2°55.76′W of Copenhagen	4,948	Gulf	1948	Dapco
	Danish-American Prospecting Co.	No. 2 Tinglev	54°55.52′N of equator 3°28.54′W of Copengahen	1,200	Gulf	1948	Dapco
			ITALY				
Prov. of Ferrara	S. P. I.	No. 5 Montalbano	———		WGC	1948	———
Lodi Area	A. G. I. P.	No. 4 Caviaga	———		WGC	1947	———
			MEXICO				
Nuevo Leon	Petroleos Mexicanos	No. 2 China	7 km. South of China	1,756.6M	GSI	1947	Pemex
Tamaulipas	Petroleos Mexicanos	No. 6 Camargo	Camargo Field	1,350′	GSI	1948	Pemex
Tamaulipas	Petroleos Mexicanos	No. 2 Trevino	Trevino Field Reynosa	11,450′	GSI	1948	Pemex
Vera Cruz	Petroleos Mexicanos	No. 1 Rancho Nuevo	San Diego de la Mar	1,980M	Pemex	1943	Pemex
Vera Cruz	Petroleos Mexicanos	No. 3 Pozo de Ojital	Ojita y Potrero	2,422M	Pemex	1944	Pemex
Vera Cruz	Petroleos Mexicanos	No. 2 Aragon	Between Francia & Aragon	1,500M	Pemex	1944	Pemex
Vera Cruz	Petroleos Mexicanos	No. 1 Soledad	Hacienda la Soledad	1,641M	Pemex	1944	Pemex
Vera Cruz	Petroleos Mexicanos	No. 1 Tepezintla	Hacienda Tepezintla	1,636M	Wesby Geo. Co.	1946	Pemex
			VENEZUELA				
State							
Apure	Mene Grande Oil Co.	No. 1 Apure District of Paez	N25,358, W86,093 (Barcelona Coords.)	8,765	Gulf	1947	?
Barinas	Socony-Vacuum Oil	No. 1 San Vicente District of Barinas	N61,767.94, W32,908.82 (Barcelona Coords.)	6,810	?	?	?
Monagas	Socony-Vacuum Oil	No. AX-1 District of Cedeno	N203,333.61, E145,377.50 (Maturin)	5,025	SSC	1946	?
Monagas	Venezuelan Atlantic Refining Co.	No. 1 Tonoro District of Maturin	N177,761.16, E131,964.36 (Maturin)	9,856	SSC of Del.	1946	?
Monagas	Consolidada	No. S.B.N.127 District of Cedeno	N257,209, E610,578 (Barcelona Coords.)	9,459	SSC of Del.	1947	?
Zulia	Mene Grande Oil Co.	No. 126-A District of Sucre	N402.8-E576.1 (Maracaibo Map Coords.)	4,050	Petty	1938	Caribbean Pet. Co.
Zul a	Mene Grande Oil Co.	No. 386 District of Sucre	N407.0-E564.9 (Maracaibo Map Coords.)	7,860	?	1939	Caribbean Pet. Co.

REVISIONS & CORRECTIONS

(corrections are *italics*)

STATE OF CALIFORNIA

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County	*Company*	*Lease*	*Location*	*Depth*	*Shot by*	*Date*	*Sponsored by*
Imperial	Texas Co.	No. 1 Grupe-Engebretson	SE 8, 16S-16E	*7,900*	Texaco	1945	CWVSG

STATE OF KANSAS

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Gray	Champlin	No. 1 *Dirks* (Becker)	C NE SW 34, 28S-29W	6,270	Stanolind	1939	OKWSA

STATE OF LOUISIANA

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Lafourche	Gulf	No. 1 Grandison Land Co.	C NE NE 14, 20S-23E	*11,986*	Gulf	*1939*	Gulf

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Natchitoches	Magnolia	No. 1 Union Sawmill	NW SE 7, 6N-6W	*9,520*	IXC	*1946*	*Magnolia*
Rapids	Union Prod.	No. 1 Belgard	NE 14, 4N-3E	*9,804*	———	1946	*Union*

STATE OF MISSISSIPPI

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Green	Humble	No. 1 Hurst	*NE SW 33, 5N-8W*	12,325	WGC	1944	Atlantic
Lawrence	Tide Water	No. 1 Denkmann Lumber Co.	C N/2 SW 5, 5N-11E	9,700	SEI	1941	*Tidewater*

STATE OF OKLAHOMA

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Kay	Shell-Conoco	No. 4-B McCormick	NW SW SE *21*, 29N-1W	*3,454*	Shell	1939	Shell

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Harper	Continental	No. 1 Howard	Sec. 15, 27N-21W	*7,770*	KVI	1946	KVI
Woods	Champlin	No. 1 Scribner	Sec. 14, 28N-19W	*7,300*	*GRC*	1946	*GRC*

STATE OF TEXAS

District: East — Pages 553 and 554 of Original Index Published in October 1944 *Geophysics*

Anderson	TWA-Seaboard	No. 2 Monnig	Sanchez No. 1-11	4,040	GSI	*1934*	*TWA-Seaboard*
Franklin	TWA-Seaboard	No. 1 Gilbert	J. Maximillian Survey	*7,855*	SEI	1943	*TWA-Seaboard*

District: Gulf Coast and South — Page 556 of Original Index Published in October 1944 *Geophysics*

Zapata	Geo. Echols	No. 1 Volpe	Porcion 32	(*REMOVE FROM 1944 LIST*)

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Brooks	Sun Oil Co.	No. 6 Sullivan	N.E. Cor. Loma Blanca Grant	*11,885*	Petty	1946	Sun

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County	*Company*	*Lease*	*Location*	*Depth*	*Shot by*	*Date*	*Sponosred by*
Cooke	Sunray	No. 1 T. C. U. (*Stark*)	Lynn Survey A-1407	*2,386*	*SSC Supervised by KVI*	1946	*Phillips*

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District: West							
Dickens	Humble	No. 1 Matador Ranch	*Sec. 26, Shock & Arnold*	7,030	Humble	1939	Humble
Pecos	Humble	No. 1 White and Baker	*Sec. 44, Blk. Z, T.C.RR*	8,800	Humble	1934	*Humble*
Reeves	Kitsos & Scott	No. 1 Burchard	Sec. 7, Blk. 58, PSL	*3,600*	NGC	1942	Stan. Tex.
Winkler	York & Harper	No. 1 Gunter-Munson	GMMB&A Sur., Blk. C, Sec. 7	4,997	SSC	1937	*Tidewater*

STATE OF WYOMING

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Converse	Carter	No. 1 Cole C-120	SW NW 19, 33N-68W	*11,540*	Carter	1946	RMSWSA

FOREIGN COUNTRIES

CANADA

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Alberta	Br. Amer.-Cal. Std.	No. 78 Wardlow Province	Lsd. 13, Sec. 23, T22-R12W, 4th	3,647	Sun	1946	*Sun*

ADDITION TO SYMPOSIUM ON "GEOPHYSICS IN MINING"*

A. H. KOSCHMANN†

Several speakers have referred to the applicability of the magnetic method of geophysical prospecting in areas of pyrrhotite bodies. Experience in the Kokomo district, Colorado, suggests that a word of caution is necessary. Massive bodies of pyrrhotite occur in the Kokomo district as replacement bodies in limestone.[1] The U. S. Bureau of Mines, in the course of a preliminary investigation of geophysical work in that area, made magnetic measurements to determine whether or not the presence of these known pyrrhotite bodies could be detected.[2]

Two reconnaissance magnetic traverses were run across one of the known pyrrhotite bodies, one approximately perpendicular and the other approximately parallel to its trend. Neither traverse showed any striking anomaly, and Swartz[3] reported that although "there appears to be a general upward departure from a line in the magnetic profile for the traverse at a right angle (E-W) to the strike, it is not at all conclusive and there is no correlation apparent with the position of the pyrrhotite."

Previous speakers have pointed out the difficulties inherent in geophysical prospecting for ore and particularly for proving ore directly. However, it appears to be generally agreed among those present that geophysical methods can render as effective indirect aid in the search for ore as in the search for oil. Among the indirect aids are geophysical methods that will identify favorable formations and structures, and determine the extension of mineral zones or belts.

The distribution of ore in definite belts that presumably are related to some deep-seated structure offers a promising field of investigation by geophysical methods. Any method that can determine such broad structures will stimulate and guide more direct methods of exploration and thus be of great aid in the search for ore.

It is now recognized that most of our western ore deposits fall in extensive

* Published by permission of the Director, U. S. Geological Survey. Manuscript received by the Editor October 14, 1948.

This manuscript was intended to be published with the other contributions to the symposium on "Geophysics in Mining" but was received too late. Its interest is such, however, that it is being presented in this manner for the benefit of those interested. *Ed.*

† U. S. Geological Survey, Denver, Colorado.

[1] A. H. Koschmann, and F. G. Wells, "Preliminary report on the Kokomo mining district, Colorado," *Colo. Sci. Soc. Proc.*, *15*, 2(1946), 48–112.

[2] J. H. Swartz, "A preliminary discussion of the results of the geophysical surveys of the Kokomo area, Colorado." Report on open file in the office of the U. S. Bureau of Mines, 1600 East First South Street, Salt Lake City 1, Utah, and in Room 224, New Customhouse, Denver, Colo.; and in the office of the U. S. Geological Survey, Room 230, New Customhouse, Denver, Colorado.

[3] *Ibid.*

belts or mineralized zones[4,5] that are measured in miles both parallel to and across their trend. Within the last two years, the United States Geological Survey has compiled a series of three maps showing the distribution of the productive metallic mineral deposits and mining districts of Colorado, Wyoming, and South Dakota; some of these data are shown on the accompanying map (Fig. 1). It will be seen that the more productive metalliferous districts of Colorado lie in a northeasterly-trending belt that extends from the San Juan Mountains in the southwest corner of the state to Boulder County on the northeast. The productive deposits of Wyoming and of the Black Hills of South Dakota also fall into a northeasterly-trending belt, though not as well defined as that of Colorado. The Colorado mineral belt reveals several significant features.

1. The most extensive mineralized area and most productive deposits lie in a relatively straight and narrow belt.

2. The mineral belt trends transversely to the mountain ranges and thus intersects several of them.

3. The ore deposits occur in rocks of diverse types and all geologic ages. In the Front Range ore occurs in granites, gneiss and schist of pre-Cambrian age; in the Gore and Mosquito Ranges the ore occurs chiefly in sedimentary rocks of Paleozoic age; and in the southwestern part of the belt, in the San Juan Mountains, the ore occurs both in sedimentary rocks of Paleozoic and Mesozoic age and in volcanic rocks of Tertiary age.

4. The belt of mineral deposits coincides with a belt of intrusive and extrusive igneous rocks of late Cretaceous and Tertiary age.

5. The mineral belt is broken by a barren gap or less productive area comprising the Gunnison River country, Colorado. However, ore deposits are found to the east of the gap, and these form an embayment with respect to the main belt.

The relation of the Colorado mineral belt to that of Wyoming and South Dakota is not clear. The Colorado mineral belt appears to end abruptly northeast of Boulder. Whether the belt ends abruptly, continues northeastward along its trend but is faulted down east of the Front Range and buried under younger sediments, or whether it is a segment of the Wyoming-South Dakota belt, has not been determined.

Critical data necessary to interpret the relations of these zones are not available because of extensive cover of alluvium and wash and the absence of underground data.

From the geologic relations of these mineral belts it is obvious that neither rock type, surface structure, nor geologic age controlled the regional distribution

[4] B. S. Butler, "Relation of Ore Deposits of the Southern Rocky Mountain Region to the Colorado Plateau," *Colo. Sci. Soc. Proc., 12* (1930), 30–33.

[5] "Ore Deposits as Related to Stratigraphic, Structural and Igneous Geology in the Western United States: Ore Deposits of the Western States" (Lindgren Volume), *Am. Inst. Min. Met. Eng.* (1933), Part I, pp. 198–240, by B. S. Butler; Part V, pp. 291–296, by W. S. Burbank; and pp. 301–307 by T. S. Lovering.

FIG. 1. Map showing mountain range
known productive lode de

ranges and the distribution and general relations of the principal
ode deposits of Colorado, Wyoming, and South Dakota.

of the ore deposits. The fact that the belt is linear, intersects mountain ranges, occurs in all rock types of all ages and coincides with a belt of porphyritic igneous rocks, implies that it is structurally and genetically related to the "grain of the continent," that is, the major control is fundamentally a deep-seated structure in the basement rocks.

Some of the information necessary to an understanding of these features might be obtained through geophysical exploration. Geophysical research should be undertaken to measure anomalies caused by these mineralized zones or belts, and the results could then be applied in determining the extension of known districts or mineralized belts. Such a program would be preliminary to further exploration and study by other means.

PATENTS*

4-ACCELEROMETER

U. S. No. 2,448,367. J. H. Goss. Iss. 8/31/48. App. 6/19/45. Assign. General Electric Co.

Decelerometer. A decelerometer for testing the cushioning property of packing material having a series of cantilever springs bearing with various degrees of pressure on adjustable contact screws, each of which is in an electric circuit connected to the grid of a thyratron.

12—ACOUSTIC MEASUREMENTS

U. S. No. 2,444,935. H. J. Kurtz. Iss. 7/13/48. App. 10/31/44.

Apparatus for Measuring Short Time Intervals. A system for measuring wave velocity in a solid with two spaced vibration pickups connected to thyratrons so that the current flowing in a circuit during the travel time between pickups may be measured on a ballistic galvanometer.

U. S. No. 2,446,835. T. J. Keary. Iss. 8/10/48. App. 6/21/46. Assign. U.S.A.

Compression-Wave Delay Device. An acoustic delay device having a column of liquid of adjustable length with a diaphragm at one end, the diaphragm being electromagnetically set into motion by a coil and the reflection from the other end of the column being picked up by a condenser plate near the diaphragm.

U. S. No. 2,447,485. P. Biquard. Iss. 8/24/48. App. 6/4/42 and 9/27/43. Assign. International Standard Electric Corp.

Supersonic Measuring Apparatus. A temperature-compensated supersonic time delay device having a source and receiver immersed in a liquid medium and with the temperature variation of velocity in the liquid adjusted to counterbalance the thermal variation of dimensions of the supports.

U. S. No. 2,448,372. C. B. Horsley. Iss. 8/31/48. App. 2/7/46. Assign. Ultrasonic Corp.

Process of Treatment By Compression Waves. A method for supersonic treatment of liquid by flowing it in a thin curtain in a chamber where the supersonic waves are generated in a gas.

16—AIRPLANE FLIGHT INSTRUMENTS

U. S. No. Re. 23,038. (Orig. No. 2,320,505). A. Z. Bendar. Iss. 9/14/48. App. 5/24/41, 6/1/43 and 11/18/44.

Flight Position and Force Indicating Instrument. An airplane altitude indicating device having a glass chamber with two immiscible liquids of different color and density and a large sphere which floats on both liquids and is also spring connected to a vertically suspended inertia weight outside the liquids.

U. S. No. 2,444,625. J. E. Bevins. Iss. 7/6/48. App. 3/15/43. Assign. Bendix Aviation Corp.

Rate-of-Turn Indicator. A gyroscopic turn indicator in which the connection between the gyro and the indicator is with a pair of springs arranged in push-pull so as to eliminate oscillations due to rough weather.

U. S. No. 2,444,708. P. Mosner and O. Steinitz. Iss. 7/6/48. App. 11/25/42.

Instrument for Navigation. An aircraft odometer in which accelerations are detected and integrated and indicated on a map.

* Abstracts by O. F. Ritzmann, Gulf Oil Corporation.

U. S. No. 2,444,933. R. E. Jasperson. Iss. 7/13/48. App. 8/7/46.

Automatic Navigational Director. An automatic director for planes or guided missiles which has two star followers sensitive to stellar radiation which measure the altitude and bearing of two stars and enter them into a computing machine which indicates course bearing and heading and actuates a controller to maintain the proper course.

U. S. No. 2,445,517. U. C. S. Dilks. Iss. 7/20/48. App. 3/4/47. Assign. U.S.A.

Pendulum Controlled Electric Dive Angle Indicator. A glide angle indicator for aircraft having a weight on a pivoted arm maintained in the flight line by two electrical contacts which control a motor which is spring connected to the arm and also carries an indicator.

U. S. No. 2,446,845. M. Morrison. Iss. 8/10/48. App. 10/2/43.

Absolute Aircraft Speedometer. A ground-speed indicator in which an image of the ground is split and one half projected to one part of a screen with a stationary mirror and the other half projected to an adjacent part of the screen with a mirror rotating at known speed and the angle between the paths of the images on the screen is measured.

U. S. No. 2,448,596. L. W. Imm. Iss. 9/7/48. App. 4/21/42. Assign. Librascope, Inc.

Flight Computer. A mechanical computing mechanism for solving trigonometric problems encountered in airplane navigation.

U. S. No. 2,449,342. G. E. Tardif. Iss. 9/14/48. App. 9/9/43.

Plotting Aircraft Navigation Computer. A mechanical navigational computer in which ground speed is obtained from wind- and air-speed settings and plotted directly on a map.

U. S. No. 2,449,976. H. G. Busignies. Iss. 9/28/48. App. 2/24/41. Assign. International Standard Electric Corp.

Tridimensional Obstacle Detection System. A terrain-clearance or collision indicator in which beams are successively directed in four horizontal quadrants and reflections picked up by antennas directional above and below the horizontal.

40—CABLE

U. S. No. 2,446,195. S. L. Shive. Iss. 8/3/48. App. 3/14/45. Assign. U.S.A.

Tester for Electrical Shieldings. A device for testing cable shielding and having a toroidal coil through which the cable may be threaded, the coil being excited by a signal generator and the cable conductors being connected to a signal-strength meter.

48—CASING PERFORATOR

U. S. No. 2,445,047. G. F. Turechek. Iss. 7/13/48. App. 1/22/40. Assign. Lane-Wells Co.

Gun Perforator. A casing perforating gun having axial powder chambers and radial gun bores intersecting each powder chamber.

U. S. No. 2,446,235. S. L. Markham. Iss. 8/3/48. App. 3/19/45. Assign. Tommy Yett.

Gun Perforator. A casing perforating gun having a powder chamber with a concave base and frusto-conical sides merging into the gun barrel.

U. S. No. 2,446,640. R. F. Davis. Iss. 8/10/48. App. 7/19/46. Assign. Well Surveys, Inc.

Well Perforator. A bullet-type casing perforator which ignites a charge of slow-burning powder in the well before the propellant charge is fired so that the bullet will encounter gas instead of liquid in the well.

88—CORE TESTING

U. S. No. 2,445,494. J. F. Redmond. Iss. 7/20/48. App. 10/10/44. Assign. Shell Development Co.

Method of Determining the Fluid Contents of Underground Formation Samples. A method of finding the connate fluid in cores by cutting the core with a pressure core barrel and while under pressure at the surface replacing the fluid extraneous to the core with mercury and then releasing the pressure and recovering connate fluids.

108—ECHO SOUNDING

U. S. No. 2,446,244. M. R. Richmond. Iss. 8/3/48. App. 5/22/43. Assign. Radio Corp. of America.

Pulse-Echo System. A pulse-echo system having improved noise discrimination and in which the output of the receiver is integrated for a short interval and the integrated output during an interval outside the maximum range of the system is balanced against the output during intervals in which a reflection signal may be expected.

U. S. No. 2,446,937. G. T. Lorance. Iss. 8/10/48. App. 3/10/45. Assign. International Projector Corp.

Echo Sounding Indicator. A portable sounding apparatus for small boats using a supersonic magnetostriction transmitter and receiver with repeated pulses sent out at a known rate and a gas-tube timing circuit to indicate depth.

U. S. No. 2,446,960. F. L. Seebinger, Jr. Iss. 10/8/48. App. 3/10/45. Assign. International Projector Corp.

Echo Sounding Indicator. A portable sounding apparatus for small boats using a supersonic magnetostriction transmitter and receiver with repeated pulses sent out at a known rate and reflection time indicated as depth.

U. S. No. 2,449,358. A. D. Zappacosta. Iss. 9/14/48. App. 2/23/46. Assign. Radio Corp. of America.

Echo Sounding System with Sensitivity Control. An echo sounding system using the same transducer for transmitting and receiving and in which the receiving circuit is paralleled by a biased rectifier so as to short circuit and protect it from high voltages during transmission.

116—ELECTRIC LOGGING

U. S. No. 2,446,303. J. E. Owen. Iss. 8/3/48. App. 11/27/43. Assign. Geophysical Research Corp.

Well Logging Apparatus. An electric well logging system using one thin electrode between two larger electrodes all connected to the same terminal of an a-c source and measuring the potential of the group and the current to the thin middle electrode so as to be able to detect thin layers.

U. S. No. 2,446,527. M. E. Chun and J. C. Stick, Jr. Iss. 8/10/48. App. 3/28/42. Assign. Lane-Wells Co.

Phase Shift Logging of Well Bores. An a-c well logging apparatus which reflects inductive or capacitive characteristics of the formations by applying ac and detecting phase shifts in the pick-up voltage by clipping it and passing it through a grid-controlled rectifier whose grids are excited ninety degrees out of phase with the applied ac.

124—ELECTRICAL PROSPECTING

U. S. No. 2,447,444. P. M. Waite. Iss. 8/17/48. App. 6/19/45.

Ground Stake. A metal stake made of a rod which is bent upon itself and has one reverted portion twisted about the other to form a screw so that the stake may be threaded into the ground.

U. S. No. 2,449,313. A. H. Naef. Iss. 9/14/48. App. 1/11/46. Assign. The Daven Co.

Ground Connecting Device. A ground stake made of a threaded rod which may be screwed into the ground through a threaded footplate.

136—EXPLOSIVE

U. S. No. 2,449,645. J. Q. du Pont and E. R. Jones. Iss. 9/21/48. App. 2/13/47. Assign. E. I. du Pont de Nemours & Co.

Blasting Plug. A tamping plug for a shot hole made up of a series of flexible disks of larger diameter than the hole alternated with resilient disks smaller than the hole, the assembly being held in conical shape by a cord which is cut after insertion in the hole.

U. S. No. 2,450,366. J. D. Williams. Iss. 9/28/48. App. 11/24/44.

Apparatus and Method for Seismographic Exploration Shooting. A device for placing a series of explosive charges in a shot hole and having a platform for the charge and upwardly diverging fingers which catch the wall of the hole and prevent upward movement when the charge below is fired.

140—FLAW DETECTOR

U. S. No. 2,447,899. G. W. Coon. Iss. 8/24/48. App. 3/27/44. Assign. Magnaflux Corp.

Method and Means for Detecting Flaws in Magnetizable Objects. A method of detecting flaws by passing a heavy direct current through the specimen and sprinkling with paramagnetic particles and agitating the particles by externally applying an alternating magnetic field close to the surface.

U. S. No. 2,447,911. M. L. Mages and G. W. Coon. Iss. 8/24/48. App. 7/20/45. Assign. Magnaflux Corp.

Magnetic Field Gauge. A magnetic pick-up head for a magnetic flaw detector having an inverted-U-shaped laminated core with a thin paramagnetic boot on the end of each leg so as to permit good magnetic contact to the specimen and with a coil on the core in a bridge circuit.

U. S. No. 2,448,399. V. G. Shaw. Iss. 8/31/48. App. 6/1/46. Assign. Sperry Products, Inc.

Supersonic Inspection. A supersonic pulse-type flaw locater in which a single transducer is used with both the pulse generator and pulse receiving amplifier connected to the transducer through a single time-delay device.

148—FLOW METER

U. S. No. 2,445,234. J. Muller. Iss. 7/13/48. App. 5/31/38 and 5/31/39.

Velocity Indicator. An electrical flow meter having a disk in a flaring pipe with axial displacement of the disk communicated to a carbon pile resistance element.

U. S. No. 2,445,854. J. C. Keyworth. Iss. 7/27/48. App. 7/5/43. Assign. Bendix Aviation Corp.

Flow Meter. An engine fuel flow meter having a manometer and a number of different sized orifices mounted on a rotatable plate so that the proper orifice may easily be selected.

U. S. No. 2,446,283. H. A. Hulsberg. Iss. 8/3/48. App. 1/31/45. Assign. Universal Oil Products Co.

Flow Measuring Device. An arrangement for measuring fluid flow through a metallic pipe having a heating coil around the pipe and two wires of a different metal connected to the pipe, one wire being connected at the heated portion and one wire connected before the heated portion, and measuring the thermal emf between the two wires.

168—GAS ANALYSIS

U. S. No. Re. 23,023. (Orig. No. 2,431,899). A. Wolf and G. Herzog. Iss. 8/3/48. App. 4/22/44, 12/2/47 and 4/30/48. Assign. The Texas Co.

Photoelectric Cell Circuit. A balanced dual photocell circuit for gas analysis or control in which one cell is shunted by a resistor and the other cell is shunted by a variable potentiometer and the voltage across the resistor and potentiometer are compared in opposition with a galvanometer.

U. S. No. 2,448,111. A. L. Nicolai. Iss. 8/31/48. App. 5/5/45.

Method and Apparatus for Measuring Constituents of Gases. A device for determining magnetic susceptibilities of gases by passing the gas through a tubular loop suspended on bearings so that it may rotate in the air gap of a magnet whose pole pieces are shaped to produce an inhomogeneous field, the torque on the loop being measured with a spiral spring and pointer as in an ammeter.

U. S. No. 2,448,206. G. B. Bailey. Iss. 8/31/48. App. 12/29/43. Assign. The Hays Corp.

Gas Analyzer. A gas analyzer of the Orsat type having a three-way control valve which extends into the burette with a capillary fit so as to prevent the liquid from rising above the 100 percent mark.

U. S. No. 2,449,067. V. Guillemin, Jr. Iss. 9/14/48. App. 7/29/46.

Constant Flow Gas Analyzer. A gas analyzer having four flow resistances connected like a Wheatstone bridge and using a differential pressure gauge as an indicator, one of the outgoing arms of the bridge having at its beginning a chemical reaction cell to remove one constituent which unbalances the bridge.

U. S. No. 2,449,485. C. Johnson. Iss. 9/14/48. App. 1/1/42. Assign. Bailey Meter Co.

Gas Analyzer. A flue-gas analyzer which determines the excess air by catalytic combustion with added fuel.

172—GEOCHEMICAL PROSPECTING

U. S. No. 2,449,627. W. J. Sweeney. Iss. 9/21/48. App. 12/14/37 and 8/9/41.

Oil Prospecting Method. A method of obtaining soil gas samples by exposing an adsorbent to the gas in the soil for a time and then removing the adsorbent and recovering the soil gas by desorption and analyzing it.

180—GRAVIMETER

U. S. No. 2,444,669. J. C. Pollard and C. F. Sellers. Iss. 7/6/48. App. 3/10/45. Assign. Robert H. Ray Co.

Support for Submerged-Area Surveying. An instrument support for prospecting over water-covered areas having a platform hung on three vertical supports, two of which are supported by tripods and the third by an A-frame.

U. S. No. 2,446,325. W. H. Gille. Iss. 8/3/48. App. 9/24/42. Assign. Minneapolis-Honeywell Regulator Co.

Leveling Support. A leveling support for an aerial camera which has motor-driven gimbals controlled by gravity sensitive pick-up units.

188—HYGROMETER

U. S. No. 2,444,613. H. R. McCombie and C. D. Wilder. Iss. 7/6/48. App. 8/31/43. Assign. U.S.A.

Low Humidity Meter. An electrical hygrometer for flowing gas in which the gas passes through sand and through magnesium chloride with embedded thermocouples which indicate the temperature difference due to the heat of absorption of water vapor.

192—INCLINOMETER

U. S. No. 2,449,674. F. H. Schmidt. Iss. 9/21/48. App. 7/12/45. Assign. Eastman Oil Well Survey Co.

Inclination Indicating Device. A bore-hole inclinometer having a pendulum suspended on gimbals and a pointed rod down the axis of the pendulum which is struck from above and driven downward into a soft record disk when a record is to be taken.

U. S. No. 2,449,704. P. Jones. Iss. 9/21/48. App. 6/26/44.

Inclinometer. A bore-hole inclinometer using a pointed pendulum and soft impression disk which is forced against it by a solenoid, recording being controlled by a plunger in a dash pot having intermediate contacts which restore the plunger when vibration occurs so that the plunger can complete its stroke and take a record only if the device has been held at rest for a time.

U. S. No. 2,449,870. W. E. Austen. Iss. 9/21/48. App. 9/11/43. and 10/19/44.

Clinometer. A mechanically-indicating clinometer using a ball-bearing-suspended pendulum which carries an indicator for a protractor scale.

200—LEVEL INDICATORS

U. S. No. 2,466,844. H. Molaver. Iss. 8/10/48. App. 6/18/46. Assign. The Oil Equipment Manufacturing Co.

Liquid Gauge. A mechanical liquid level indicator for a tank having a float on a long pivoted arm connected to an indicator, the entire assembly being installed through the bushing on which the indicator is mounted.

216—MAGNETIC COMPASS

U. S. No. 2,446,568. L. Wolfe. Iss. 8/10/48. App. 5/16/44.

Magnetic Compass. A compass having its magnet in two coaxial pieces suspended from the compass card and a metal cup extending up under the card near the inner ends of the magnet pieces to provide eddy-current damping.

U. S. No. 2,447,496. M. C. Depp, R. S. Curry, Jr. and C. F. Fragola. Iss. 8/24/48. App. 2/3/44. Assign. The Sperry Corp.

Flux Valve System and Method of Operation. A flux-valve compass having three cores 120° apart excited by a vertical coil in the center supplied with half-wave rectified current and with the horizontal pick-up coils connected in opposition to cancel out the excitation effect and produce a compass indication at fundamental frequency.

228—MAGNETIC TESTING

U. S. No. 2,444,751. K. L. Scott. Iss. 7/6/48. App. 2/12/46. Assign. Western Electric Co., Inc.

Method and Apparatus for Sorting Magnetic Materials According to Their Residual Magnetism. A magnetic sorting device in which the specimen is held in a magnetic field and then dropped through a coil whose output is amplified and relayed to a sorting mechanism.

U. S. No. 2,446,977. R. L. Manegold and I. H. Wynne. Iss. 8/10/48. App. 12/22/45. Assign. Dings Magnetic Separator Co.

Art of Detecting Tramp Material. A method of making tramp material detectable in ore by embedding small pieces of permanently magnetized material in the parts of the equipment from which the tramp is likely to come.

U. S. No. 2,448,111. A. L. Nicolai. Iss. 8/31/48. App. 5/5/45.

Method and Apparatus for Measuring Constituents of Gases. A device for determining magnetic susceptibilities of gases by passing the gas through a tubular loop suspended on bearings so that it may rotate in the air gap of a magnet whose pole pieces are shaped to produce an inhomogeneous field, the torque on the loop being measured with a spiral spring and pointer as in an ammeter.

U. S. No. 2,448,794. T. T. Goldsmith, Jr. and E. R. Mann. Iss. 9/7/48. App. 6/4/43. Assign. Allen B. Du Mont Laboratories, Inc.

Device for Testing Magnetic Materials. A magnetic testing arrangement in which the specimen is

used as a core for both high-frequency and low-frequency excitation and a c-r tube connected to the exciting coils so that the high frequency is on one set of plates and the low frequency on the other.

U. S. No. 2,450,166. N. S. Rich. Iss. 9/28/48. App. 8/18/44.

Electrical Detection Apparatus. A device for detecting vehicles for traffic-signal control having an inductance wound on a high-permeability open core exposed to the magnetic field of the vehicle, the inductance having a series condenser and a resistor which is in the grid circuit of a tube which actuates a relay.

232—MAGNETOMETER

U. S. No. 2,444,669. J. C. Pollard and C. F. Sellers. Iss. 7/6/48. App. 3/10/45. Assign. Robert H. Ray Co.

Support for Submerged-Area Surveying. An instrument support for prospecting over water-covered areas having a platform hung on three vertical supports two of which are supported by tripods and the third by an A-frame.

U. S. No. 2,447,849. C. H. Fay. Iss. 8/24/48. App. 12/26/44. Assign. Shell Development Co.

Magnetometer. A magnetometer having an elastically suspended coil carrying a mirror which reflects a beam of light onto a photocell, the photocell output being amplified and an a-c signal fed back to the coil to sustain oscillation and a rectified signal fed into Helmholtz coils which neutralize the ambient field, indication being obtained by the Helmholtz coil current necessary to just maintain oscillation.

U. S. No. 2,447,880. J. D. Seaver. Iss. 8/24/48. App. 8/24/45. Assign. General Electric Co.

Magnetometer. A device for measuring the field strength across small air gaps and having a permanent magnet mounted at the end of a long pivoted shift which turns against a spring.

U. S. No. 2,448,613. F. G. Merrill. Iss. 9/7/48. App. 5/16/47. Assign. Bell Telephone Laboratories, Inc.

Magnetic Detector. A flux-valve magnetometer excited at a fundamental frequency and with a second harmonic filter in its output circuit and having connected across the flux-valve winding a frequency selective shunt which passes only the third harmonic in order to minimize the effect of excitation voltage changes.

236—MASS SPECTROMETRY

U. S. No. 2,444,968. H. W. Washburn. Iss. 7/13/48. App. 12/9/43. Assign. Consolidated Engineering Corp.

Mass Spectrometry. A mass spectrometer having a shield around the filament to prevent changes in the ion-accelerating potential from affecting the electron beam and also to protect the filament from positive ion bombardment.

U. S. No. 2,446,191. J. C. Pemberton. Iss. 8/3/48. App. 3/16/46. Assign. Consolidated Engineering Corp.

Switching Mechanism for Electrical Computers. A mounting arrangement for potentiometers on a rotatable cylinder in which the resistances represent elements of a system of simultaneous equations and are conveniently repeatedly adjusted to simulate the iterative method of solving the equations.

244—MICROPHONE

U. S. No. 2,444,911. H. Benioff. Iss. 7/13/48. App. 12/4/42. Assign. Submarine Signal Co.

Acoustic Structure. A streamlined housing for a hydrophone, the housing having an outer shell of steel and an inner shell of aluminum with the intervening space filled with viscous pitch to damp out transverse vibrations set up by oblique transmission through the housing.

276—PERMEABILITY TESTING

U. S. No. 2,446,588. G. Herzog and A. Wolf. Iss. 8/10/48. App. 4/4/44. Assign. The Texas Co.

Method of Determining the Permeability of Substrata. A method of determining permeability by forcing into the formation a fluid containing a radioactive substance and measuring the rate of increase of radioactivity of the stratum with a detector suspended opposite the formation.

U. S. No. 2,448,955. W. A. Bruce. Iss. 9/7/48. App. 6/1/45. Assign. Standard Oil Development Co.

Method and Apparatus for Measuring Permeability. A device for measuring permeability of rock fragments which has a hand-operated cylinder pump one end of which has a perforated soft rubber seal which may be pressed against the specimen, after which the piston is pulled out to the end of its stroke and the subsequent rate of pressure rise in the cylinder observed on a gauge.

288—PRESSURE GAUGE

U. S. No. 2,446,632. L. D. Cahill and V. T. Uber. Iss. 8/10/48. App. 1/31/44. Assign. Jack & Heintz Precision Industries, Inc.

Air Pressure Gauge. A device for detecting variations in internal diameter of a bore having a plug with diametrically opposed orifices which may be inserted into the bore and pressure variations detected by a differential bellows connected between the plug and a regulated air supply.

U. S. No. 2,447,817. F. Rieber. Iss. 8/24/48. App. 1/29/44. Assign. Interval Instruments, Inc.

Temperature or Pressure Responsive Variable Frequency Oscillator. A pressure gauge having a fine wire in sustained vibration in a permanent magnet field with the tension on the wire varied by connecting it to a pressure diaphragm and the frequency of oscillation indicated.

U. S. No. 2,448,322. R. G. Piety. Iss. 8/31/48. App. 9/20/43. Assign. Phillips Petroleum Co.

Detonation Meter. A knock meter for internal combustion engines having a magnetostriction pressure gauge, amplifier and circuits for eliminating valve clatter and spark interference and which indicates the peak knock voltage and also indicates it on a c-r tube screen.

U. S. No. 2,448,323. D. R. De Boisblanc. Iss. 8/31/48. App. 8/9/44. Assign. Phillips Petroleum Co.

Detonation Meter. A knock meter for internal combustion engines having a magnetostriction pressure gauge, an amplifier and a filter to remove unwanted pressure impulses and a threshold circuit which passes the signal to an exponential pulse generator and then to a sustained pulse generator so that the peak may be indicated on a voltmeter.

304—RADIOACTIVITY LOGGING

U. S. No. 2,445,305. F. P. Hochgesang. Iss. 7/13/48. App. 12/13/44. Assign., Socony-Vacuum Oil Co., Inc.

Radiation Detector. A radioactivity logging apparatus having concentric ionization chambers of increasing wall thickness and separately recorded so that a spectral analysis of the formation radiation is obtained.

U. S. No. 2,446,588. G. Herzog and A. Wolf. Iss. 8/10/48. App. 4/4/44. Assign. The Texas Co.

Method of Determining the Permeability of Substrata. A method of determining permeability by forcing into the formation a fluid containing a radioactive substance and measuring the rate of increase of radioactivity of the stratum with a detector suspended opposite the formation.

U. S. No. 2,450,265. A. Wolf. Iss. 9/28/48. App. 4/4/44. Assign. The Texas Co.

Method of Logging Boreholes. A radioactivity logging method in which a lighter radioactive liquid is placed in a part of the well and forced down by pressure and followed by a radioactivity detector

maintained a fixed distance above the fluid interface, the rate of increase of detected radioactivity being proportional to the permeability and the total increase in radioactivity being proportional to the porosity.

308—RADIOACTIVITY MEASUREMENTS

U. S. No. 2,449,697. A. Graves and T. J. Dawes. Iss. 9/21/48. App. 4/12/45 and 3/19/46. Assign. Alltools, Ltd.

Ionization Chambers, Geiger-Müller Tubes, and the Like. An ionization counter having a short cathode wire suspended at the center of a semicylindrical anode and enclosed in a glass envelope filled with inert gas.

312—RADIO NAVIGATION

U. S. No. 2,444,445. E. J. Isbister. Iss. 7/6/48. App. 11/10/43. Assign. The Sperry Corp.

Radio Navigation System. A system of radio navigation in which the difference in distances of the receiver to fixed stations is observed, the receiver having selectors which identify and segregate the signals from each station and gives the differences automatically.

U. S. No. 2,444,578. J. Neufeld. Iss. 7/6/48. App. 6/16/42.

Navigational Method and Apparatus. A blind landing system in which vertical navigation is obtained from a transmitter on the ground radiating horizontally-polarized waves and an indicator on the plane indicating the angle between the longitudinal axis of the ship and a bearing to the transmitter.

U. S. No. 2,445,361. G. Mountjoy, G. D. Hulst, Jr. and L. Schoenfeld. Iss. 7/20/48. App. 4/20/45. Assign. Radio Corp. of America.

Radio Navigation System. A Shoran system in which the larger part of the time difference to be measured is obtained on a slow-moving c-r trace with large time units and the fractional part is obtained on a fast-moving trace with smaller time units and with selective switching so either one may be used.

U. S. No. 2,449,977. H. G. Busignies, Iss. 9/28/48. App. 6/30/45. Assign. Federal Telephone and Radio Corp.

Location Indicating System. A radio navigation system using two radio beacons whose beams have different speeds of rotation and a repeating station which operates when both beacons act on it, the receiving system having synchronously rotating slotted disks for viewing circular gas discharge lamps which are fired from the received beacon signals.

316—RADIO RANGING

U. S. No. 2,445,014. I. Wolff. Iss. 7/13/48. App. 11/29/43. Assign. Radio Corp. of America.

Vibratory Mechanical System. A vibrating drive for obtaining a motion whose velocity is a predetermined function of time by applying a force having a component which varies linearly with the velocity, a component which varies with the time integral of the velocity and a component which varies with the time derivative of the velocity.

U. S. No. 2,445,779. R. Hardy. Iss. 7/27/48. App. 12/28/40 and 5/24/43. Assign. International Standard Electric Corp.

Electromagnetic Wave Direction Responsive Apparatus. A stationary radio direction finder having two pairs of oppositely wound loops connected to tubes which are biased by circular scanning voltages also applied to the c-r tube plates.

U. S. No. 2,446,244. M. R. Richmond. Iss. 8/3/48. App. 5/22/43. Assign. Radio Corp. of America.

Pulse-Echo System. A pulse-echo system having improved noise discrimination and in which the output of the receiver is integrated for a short interval and the integrated output during an interval outside the maximum range of the system is balanced against the output during intervals in which a reflection signal my be expected.

U. S. No. 2,446,520. D. Blitz. Iss. 8/10/48. App. 4/17/45. Assign. Radio Corp. of America.

Transmitter for Distance Determining System. A system for compensating d-c supply voltage variations in a frequency-modulated pulse-echo system by connecting the supply voltage across a resistor at the high end of the converted high voltage supply through a rotating switch and using the resulting wave to control the modulator.

U. S. No. 2,446,630. N. W. Bryant, E. E. Crump, M. R. Dungan and J. Strand. Iss. 8/10/48. App. 5/2/44. Assign. Bell Telephone Laboratories, Inc.

Range Measurements. A radar system stabilized with a saturable-core reactor in the pulse-rate circuit so that more accurate reflection-time measurements may be obtained.

U. S. No. 2,446,850. C. S. Root. Iss. 8/10/48. App. 11/30/42. Assign. General Electric Co.

Radio Echo Apparatus. A radio ranging apparatus using two spaced receiving antennas whose signals are separately indicated on a c-r tube screen with provision to displace one indication on the screen without displacing the other.

U. S. No. 2,447,502. R. J. Hardy. Iss. 8/24/48. App. 4/20/40 and 11/27/41. Assign. International Standard Electric Corp.

System for Radio Direction Finding and Similar Purposes. A radio ranging indicator having a rotating directive antenna and a synchronously rotating c-r tube spot which has a radial oscillation and is extinguished at a minimum received signal.

U. S. No. 2,447,728. F. E. Bartholy. Iss. 8/24/48. App. 10/28/42. Assign. Westinghouse Electric Corp.

Radio Direction and Range Indicator. A radar system in which the dial indicating the bearing of the antenna is stroboscopically illuminated by an electron-ray tube illuminated by the received signal and with the angular spread of tube illumination indicating the range.

U. S. No. 2,448,041. R. Marchand. Iss. 8/31/48. App. 11/25/44. Assign. Federal Telephone and Radio Corp.

Direction Finder. A radio direction finder of the amplitude comparison type using four antennas which are switched in succession to a receiver whose output is synchronously switched to the plates of a c-r tube.

U. S. No. 2,448,059. A. D. Smith, Jr. and H. M. Guthman. Iss. 8/31/48. App. 5/29/43 and 5/21/45. Assign. Federal Telephone and Radio Corp.

Oscillograph Trace Control System. A method of obtaining a four-sided tracing on a c-r tube screen by producing two waves with alternate cycles of scanning and deflecting potentials and applying one to the x-deflecting plates and one to the y-deflecting plates.

U. S. No. 2,449,175. W. J. O'Brien. Iss. 9/14/48. App. 5/13/43 and 7/24/44. Assign. The Decca Record Co., Ltd.

Radio Direction Finder. An automatic radio direction finder using two directional antennas whose signals are modulated and the phase displacements indicated by stroboscopic illumination of a dial by a gas-discharge tube.

U. S. No. 2,449,553. P. G. Hansel. Iss. 9/21/48. App. 9/14/45.

Radio Compass. A radio direction finder using two spaced non-directional antennas which pick up signals differing in phase and whose signals are amplitude-modulated and combined to produce a phase-modulated signal which is detected and indicated.

U. S. No. 2,449,859. H. F. Penfold and J. P. Della Corte. Iss. 9/21/48. App. 1/27/44. Assign. Fairchild Camera and Instrument Corp.

Automatic Radio Compass. A radio direction finder in which the signal from a loop antenna is modulated, detected and combined with the signal from a non-directional antenna and a phase discriminator used to control a servomotor which orients the loop.

U. S. No. 2,449,978. T. H. Clark. Iss. 9/28/48. App. 6/30/45. Assign. Federal Telephone and Radio Corp.

Radio Direction Finder. A radio direction finding system using four antennas shielded from each other and a commutator which successively feeds their signals to a c-r tube, the signals being balanced by an attenuator coupled to the indicating dial.

U. S. No. 2,450,014. J. H. Newitt. Iss. 9/28/48. App. 10/28/44. Assign. Federal Telephone and Radio Corp.

Electronic Goniometer for Radio Direction Finders. A radio direction finder using four antennas in an Adcock array whose signals are modulated by an oscillator which synchronously also controls the indicator.

U. S. No. 2,450,341. W. D. Hershberger. Iss. 9128/48. App. 9/28/40. Assign. Radio Corp. of America.

Sensitive Distance Measurement Device. A radio pulse-echo system which is keyed alternately at a high rate and at a low rate and the indication given on a main scale and on a vernier scale.

324—RECORDER

U. S. No. 2,445,272. J. H. Keegan. Iss. 7/13/48. App. 12/15/44. Assign. The Brown Instrument Co.

Recording Instrument Having Plural Pens and an Oscillating Actuator. A multi-point temperature recorder in which the bridge is sequentially connected to each thermocouple, balanced and recorded with the appropriate pen.

U. S. No. 2,445,832. E. W. Kellogg. Iss. 7/27/48. App. 11/19/43. Assign. Radio Corp. of America.

Variable Time Sound Recording Method and System. A variable density recording system in which the light from a single-ribbon light valve is reflected at almost grazing incidence from a front surface mirror so as to produce a beam with two movable edges.

U. S. No. 2,446,324. U. L. Di Ghilini. Iss. 8/3/48. App. 5/26/43.

Recording and Reproducing Apparatus. A phonograph recorder in which constant groove speed is attained by driving the turntable with a friction wheel which engages the bottom side of the turntable opposite the recording head and moves radially with the recording head.

U. S. No. 2,446,479. S. J. Begun. Iss. 8/3/48. App. 9/17/42. Assign. The Brush Development Co.

Method and Apparatus for Correcting Phase Shift Distortion in Sound Recording Systems. A system for eliminating phase shift distortion in a phonograph recording by making a second recording from the first record run backwards and then playing back the second record backwards.

U. S. No. 2,447,752. C. M. Hathaway. Iss. 8/24/48. App. 10/26/42 and 1/30/46.

Apparatus for Recording an Oscillographic Record. A transient recorder in which the transient

starts the recording through the action of relays which are rendered ineffective if the recording paper supply is empty.

U. S. No. 2,449,291. P. S. Gay. Iss. 9/14/48. App. 2/26/40 and 8/20/41. Assign. Wilcox-Gay Corp.

Recording Apparatus Volume Level Indicator. A volume level indicator for a phonograph recorder using two R-C circuits connected to the grid of an electron-ray indicator tube.

344—SEISMOGRAPH AMPLIFIER

U. S. No. 2,446,195. S. L. Shive. Iss. 8/3/48. App. 3/14/45. Assign. U.S.A.

Tester for Electrical Shieldings. A device for testing cable shielding and having a toroidal coil through which the cable may be threaded, the coil being excited by a signal generator and the cable conductors being connected to a signal strength meter.

360—SEISMOGRAPH PROSPECTING

U. S. No. 2,449,921. A. Wolf. Iss. 9/21/48. App. 12/24/43. Assign. The Texas Co.

Seismic Method of Locating Faults. A method of locating faults by shooting split spreads on a line at right angles to the strike of the fault and recording reflections from horizontal beds and simultaneously also recording so as to cancel reflections from horizontal beds and comparing the two recordings.

U. S. No. 2,450,352. R. G. Piety. Iss. 9/28/48. App. 7/25/44. Assign. Phillips Petroleum Co.

Seismic Wave Correction Means and Method. A method of seismograph recording using a tuned amplifier and a time-delay network producing one-half cycle delay, the output from the amplifier and from the delay network being added and recorded.

U. S. No. 2,450,366. J. D. Williams. Iss. 9/28/48. App. 11/24/44.

Apparatus and Method for Seismographic Exploration Shooting. A device for placing a series of explosive charges in a shot hole and having a platform for the charge and upwardly diverging fingers which catch the wall of the hole and prevent upward movement when the charge below is fired.

368—SEISMOGRAPH TIMING

U. S. No. 2,448,812. J. Lemire. Iss. 9/7/48. App. 9/30/46. Assign. fifty percent to N. Boisvert.

Electric Timing Motor. A timing motor having a vibrator which is linked to a rotatably mounted disk by means of a one-way claw so that the disk is rotated in one direction.

372—SEISMOGRAPH VOLUME CONTROL

U. S. No. 2,444,676. F. W. Roberts and R. C. Curtis. Iss. 7/6/48. App. 12/29/44. Assign. Dictaphone Corp.

Sound Recording and Reproducing Control System. A quick-acting avc system for an audio amplifier in which the avc bump and distortion is cancelled by being applied to two tubes in opposite phase.

376—SEISMOMETER

U. S. No. 2,449,085. R. A. Peterson. Iss. 9/14/48. App. 12/12/44. Assign. United Geophysical Co., Inc.

Submersible Seismometer System. A water mount for a seismograph detector having a non-resonant platform for supporting the detector suspended beneath the surface of the water by a float.

380—SEISMOMETER TESTING

U. S. No. 2,445,014. I. Wolff. Iss. 7/13/48. App. 11/29/43. Assign. Radio Corp. of America.

Vibratory Mechanical System. A vibrating drive for obtaining a motion whose velocity is a pre-

determined function of time by applying a force having a component which varies linearly with the velocity, a component which varies with the time integral of the velocity and a component which varies with the time derivative of the velocity.

U. S. No. 2,446,818. S. Flam. Iss. 8/10/48. App. 11/25/44.

Vibrator. A vibrating platform for cement casting which is suspended on a double cantilever arm and has motor-driven eccentric weights, the frequency being adjusted by moving a spacing block between the cantilevers.

384—SHOT HOLE CASING

U. S. No. 2,449,037. T. O. Harkness. Iss. 9/7/48. App. 11/30/45. Assign. C.H.C. Patent Corp.

Method of Seismic Exploration Operations. A method of seismograph shooting in which a light-weight shot-hole casing having a wall thickness between 0.055 and 0.075 inch is used so that the casing will collapse inwardly adjacent to the explosion.

400—SOIL GAS SAMPLING

U. S. No. 2,449,627. W. J. Sweeney. Iss. 9/21/48. App. 12/14/37 and 8/9/41.

Oil Prospecting Method. A method of obtaining soil gas samples by exposing an adsorbent to the gas in the soil for a time and then removing the adsorbent and recovering the soil gas by desorption and analyzing it.

416—SPECTROGRAPH

U. S. No. 2,444,560. R. Feldt and C. Berkley. Iss. 7/6/48. App. 4/15/44. Assign. Allen B. Du Mont Laboratories, Inc.

Cathode-Ray Tube Spectrograph. A system for showing a spectrum on a c-r tube screen by repeatedly scanning the spectrum with a mirror whose image falls on a photomultiplier tube connected to the vertical deflecting plates and the horizontal sweep synchronized with the scanning.

U. S. No. 2,446,874. J. Geffner and E. R. Millen. Iss. 8/10/48. App. 5/11/44. Assign. Fisher Scientific Co.

Electronic Apparatus for Spectrographic Analysis. A spherical grating spectrograph having electron multiplier photocells which pick up the spectral lines and integrating circuits to measure the intensity.

420—SPECTROPHOTOMETER

U. S. No. 2,445,874. D. R. De Boisblanc and H. M. Barton, Jr. Iss. 7/27/48. App. 6/1/44. Assign. Phillips Petroleum Co.

Radiation Thermopile and Method of Making the Same. A thermopile for spectroscopic measurements made of an evaporated metal film with superimposed thin metal plates and cut into a spiral strip.

428—STRAIN GAUGE

U. S. No. 2,445,340. H. R. Thomas. Iss. 7/20/48. App. 7/30/46.

Long Base Strain or Distance Gauge. A device for measuring dimension changes of structures in which a steel tape line is anchored at one point and the other end of the line fastened to a rotating quadrant kept under constant torque and having a precision spirit level and divided vertical circle to detect rotation.

U. S. No. 2,445,455. H. T. Rights and H. Toomin. Iss. 7/20/48. App. 12/5/41. Assign. Westinghouse Electric Corp.

Electrical Micrometer Gauge. A variable-air-gap reluctance-bridge type electrical strain gauge in which the ac from two legs are separately rectified and the difference indicated.

U. S. No. 2,445,880. C. M. Hathaway. Iss. 2/27/48. App. 11/8/43 and 5/10/45. Assign. Hathaway Instrument Co.

Electrical Strain Measuring Apparatus. A variable impedance bridge-type displacement measuring circuit using two bridge-type rectifiers energized from the same source as the impedance bridge and having a differentially-connected indicating meter.

U. S. No. 2,447,208. G. H. Rendel. Iss. 8/17/48. App. 5/17/45. Assign. Carnegie-Illinois Steel Corp.

Extensometer for Indicating Percent Elongation. An extensometer for indicating the elongation of strip in a rolling mill and having a generator driven at the differential speed of succeeding rolls and also a generator on the entering roll and a circuit for comparing the generated voltages.

U. S. No. 2,447,209. G. H. Rendel and T. F. Reed. Iss. 8/17/48. App. 6/28/46. Assign. One half to Carnegie-Illinois Steel Corp. and one-half to United States Steel Corp.

Extensometer for Indicating Amount of Elongation of Strip Material. An extensometer for indicating the elongation of strip in a rolling mill and having a generator driven at the differential speed of succeeding rolls and a self-balancing bridge to indicate its output.

U. S. No. 2,447,517. S. S. Manson. Iss. 8/24/48. App. 3/12/45.

Electrical Analyzer for 45° Strain Rosette Data. An electrical network containing capacity, resistance and inductance operated at resonance for computing the maximum shear strain and major and minor principal strains from the indications of three filament-type strain gauges set at 0°, 45° and 90°

436—SUBMARINE SIGNALING

U. S. No. 2,444,911. H. Benioff. Iss. 7/13/48. App. 12/4/42. Assign. Submarine Signal Co.

Acoustic Structure. A streamlined housing for a hydrophone, the housing having an outer shell of steel and an inner shell of aluminum with the intervening space filled with viscous pitch to damp out transverse vibrations set up by oblique transmission through the housing.

U. S. No. 2,444,967. E. E. Turner, Jr. Iss. 7/13/48. App. 3/23/36. Assign. Submarine Signal Co.

Oscillator. A submarine signaling oscillator having a radiating plate with concentric magnetostrictive rings on its back surface.

U. S. No. 2,447,333. H. C. Hayes. Iss. 8/17/48. App. 12/30/31. Assign. U.S.A.

Ultra-Audible Sound Reception. A directive listening system for detecting propeller noise using a directive ultrasonic hydrophone and indicating the modulation of the ultra-audible signal received.

U. S. No. 2,448,787. C. B. Ferrel. Iss. 9/7/48. App. 12/22/41 and 8/18/44. Assign. Ferrel Industries, Inc.

Apparatus for Detecting and Locating Enemy Vessels. A sonic-radio buoy which has a rotating directional hydrophone whose output is amplified and the direction of maximum signal coded and transmitted by radio together with a coded identification signal.

460—THERMOMETER

U. S. No. 2,447,816. F. Rieber. Iss. 8/24/48. App. 1/29/44. Assign. Interval Instruments, Inc.

Temperature Responsive Variable Frequency Oscillator. A temperature indicator having a fine wire in sustained vibration in a permanent magnet field with the tension on the wire varied by a bimetallic strip and the frequency of oscillation indicated.

468—TIME INTERVAL METER

U. S. No. 2,444,917. A. B. J. Clark. Iss. 7/13/48. App. 7/9/45.

Single-Electrode High-Speed Recording Device. A rotating-drum spark chronograph whose sparking electrode is enclosed in a tube and has an intermediate spark gap in series as so to reduce the area of wandering of the recording spark.

U. S. No. 2,444,935. H. J. Kurtz. Iss. 7/13/48. App. 10/31/44.

Apparatus for Measuring Short Time Intervals. A system for measuring wave velocity in a solid with two spaced vibration pickups connected to thyratrons so that the current flowing in a circuit during the travel time between pickups may be measured on a ballistic galvanometer.

472—TIMEPIECE TESTING

U. S. No. 2,445,916. J. L'Eplattenier. Iss. 7/27/48. App. 1/22/43 and 12/21/43.

Watch Timing Apparatus. A watch timer in which the ticks are amplified and used to energize a relay whose contact circuit is in series with that of a standard watch, coincidences being used to start and stop a chronograph which indicates the error.

484—TRANSDUCER

U. S. No. 2,444,726. W. H. Bussey. Iss. 7/6/48. App. 2/5/44. Assign. The Bristol Co.

Method and Apparatus for Determining the Magnitude of a Condition. A telemetering transmitter having an induction balance with one of its secondary windings subjected to a dc which varies with the condition being measured.

U. S. No. 2,444,967. E. E. Turner, Jr. Iss. 7/13/48. App. 3/23/36. Assign. Submarine Signal Co.

Oscillator. A submarine signaling oscillator having a radiating plate with concentric magnetostrictive rings on its back surface.

U. S. No. 2,445,276. F. Massa. Iss. 7/13/48. App. 5/4/45.

Electrodynamic Loudspeaker. A direct-radiator type of electrodynamic speaker of high efficiency whose coil mass and conductor volume is specified in relation to the coil diameter.

U. S. No. 2,445,318. K. R. Eldredge, A. Hundere and J. H. Macpherson, Jr. Iss. 7/20/40. App. 10/23/43. Assign. California Research Corp.

Magnetostrictive Pickup Unit. A detonation detector for mounting on the outside of an internal-combustion engine cylinder and having a magnetostrictive tube with a mass on one end.

U. S. No. 2,446,428. F. D. Merrill, Jr. Iss. 8/3/48. App. 11/3/44. Assign. Radio Corp. of America.

Apparatus for Producing Indications of Movement of an Element. A system for remotely indicating the reading of a meter by mounting an r-f condenser plate on its pointer to change the frequency of a radio transmitter which is picked up by a receiver having fixed tuning.

U. S. No. 2,447,212. J. F. Schoeppel. Iss. 8/17/48. App. 11/13/44. Assign. Minneapolis-Honeywell Regulator Co.

Variable Inductance Pickup Device. An electric control device having an open-cored primary unit with a distributed winding and stray flux and a transversely placed secondary unit which picks up the stray flux.

U. S. No. 2,447,818. F. Rieber. Iss. 8/24/48. App. 1/11/45. Assign. Interval Instruments, Inc.

Periodic Reversing Drive. A mechanical device for converting rotary motion to oscillatory motion

in which a round shaft frictionally engages an inside surface of a slot with reversal effected by transferring the shaft to the opposite side of the slot and with the friction produced by magnetic attraction between the shaft and the side of the slot.

U. S. No. 2,449,166. W. D. Hershberger. Iss. 9/14/48. App. 6/15/44 and 5/14/45. Assign. Radio Corp. of America.

Microwave-Acoustic Light Valve. A light valve in which modulated microwaves are passed into a microwave-absorbing gas which generates supersonic waves which in turn are transmitted into a liquid whose varying density pattern is used to control the light from the lamp.

U. S. No. 2,450,104. L. E. Barton. Iss. 9/28/48. App. 11/30/42. Assign. Radio Corp. of America.

Electroacoustical Transducer. A magnetostriction hydrophone in which magnetostrictive tubes are fastened to the diaphragm with the free end of the tubes extending into recesses in a backing plate.

492—VIBROMETER

U. S. No. 2,447,863. E. L. Kent and R. C. Treseder. Iss. 8/24/48. App. 5/9/44. Assign. Kent to C. G. Conn, Ltd.

Vibration Indicating Apparatus. A vibrometer having a vibrating reed which carries a normally closed shutter, vibration of which allows light to fall on a photocell connected to a meter indicating the product of frequency and amplitude.

500—VOLTMETER

U. S. No. 2,449,068. R. Gunn. Iss. 9/14/48. App. 8/28/44.

Electric Field or Potential Indicator. An electrostatic-field indicator having an electrode exposed to the field and periodically shielded and in parallel with it another electrode periodically and synchronously exposed to a neighboring electrode of adjustable known potential, the two parallel electrodes being connected to a vacuum tube to indicate balance of the fields.

516—WELL SIGNALING

U. S. No. 2,449,138. D. M. Phillips. Iss. 9/14/48. App. 7/5/43. Assign. Chiksan Tool Co.

Rotatable Electrical Connection. A rotatable electric connector having telescoping parts running on ball bearings and carbon brushes which bear on concentric conductors.

520—WELL SURVEYING

U. S. No. 2,450,060. R. Ring. Iss. 9/28/48. App. 11/20/45. Assign. Sperry-Sun Well Surveying Co.

Well Surveying Instrument. An electrolytically recording well surveying instrument in which the electric circuit is maintained closed by a bimetallic strip so long as the temperature increases but is broken when the temperature decreases on coming out of the hole.

REVIEWS

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Submarine Geology by Francis P. Shepard. New York: Harper and Brothers, 1948. Pp. 338.

This book contains a great deal of useful and interesting information for geophysicists, especially those in this profession who are spending more of their time at sea. After reading this book, the reviewer is entirely in accord with the remarks made in Dr. Croneis' introduction and will therefore let excerpts from it suffice for a general review of the material contained therein. However, he would like to add a few supplementary remarks regarding specific portions of this book that are of particular interest to geophysicists. Dr. Shepard's chapter on the economic applications of submarine geology definitely falls in this category, especially the sections dealing with continental shelf investigations and oil possibilities and the mapping of oil structures on the continental shelves, as well as those portions devoted to the origin and history of the continental shelves and to the topography and sediments encountered thereon. The marine geophysicist will be in a much better position to interpret his data after studying these chapters. Dr. Shepard has also done a remarkable job in collecting and evaluating the many references on the subject of marine geology and geophysics which are scattered through an unusually extensive and diversified group of professional periodicals and other types of publications.

Those portions of Dr. Croneis' introduction which serve to describe the book as a whole are as follows:

"Shepard's *Submarine Geology* . . . is the pioneer textbook in English on this important subject. Indeed, in the strictest sense, this is the first actual *text* in any language on the too little known geology of the water-washed three-quarters of the face of the earth. As such, it complements the two somewhat related reference volumes, Sverdrup, Johnson, and Fleming's *The Oceans*, and R. A. Daly's *The Floor of the Ocean*. It also brings up to date, and makes more usable to students, some of the essential material of Murray and Renard's *Challenger Report*. In addition, the present work reinterprets part of the data found in Douglas Johnson's *Shore Processes and Shoreline Development*. *Submarine Geology* also makes readily available in text form the results of some of the most significant recent researches on the ocean bottoms, including those carried on under military aegis during the Second World War.

"The modern approach followed in *Submarine Geology* is of special value because Andree's *Geologie des Meeresbodens* was printed as long ago as 1920. Although a semi-monumental compendium, Andree's publication has never become widely used by North American students, even as a reference work, and it is now somewhat out of date. Similarly Dangeard's *Geologie Sous-Marine de la Manche*, also published some twenty years ago, has not been widely available to American geologists.

"*Submarine Geology* is divided into twelve chapters. Each of these carries the mark of Dr. Shepard's authentic and firsthand knowledge of the field in which he himself has been a pioneer. As a consequence, some portions of the book may well come to be regarded as iconoclastic, for the data presented will not only enlarge the experience but alter some of the views of professional geologists and younger students of geology alike. The author's treatment of the controversial topics of Continental Shelves, Continental Slopes, and Submarine Canyons is especially vigorous and stimulating. The discussion of Coral Reefs and the Floor of the Deep Oceans is scarcely less so.

"In addition, all of the many who love the sea should discover much of real interest in this book; and all serious students of the Earth Sciences may well come to regard it as an indispensable reference."

R. A. GEYER

Canadian Geophysical Bulletin of the National Research Council of Canada. Issued Quarterly by the Associate Committee on Geodesy and Geophysics, Ottawa, Vol. II, No. 1 (January 1–March 31, 1948).

This issue of the quarterly starts its second year and the contents and format follow essentially the same scheme as for the first. The results of geophysical activity in Canada, together with proposed future operations, are presented for the fields of meteorology, hydrology, oceanography, seismology, terrestrial magnetism, atmospheric ionization, geodesy (including gravity), tectonics, geothermometry, and radioactivity. The bibliographies which accompany each section of this bulletin also serve a very useful purpose in making readily available references on pure and applied geophysical subjects appearing primarily in Canadian journals.

In the section on terrestrial magnetism, a short note on the work done with the airborne magnetometer acquired from the United States Navy is presented. A 3,000-square-mile survey was made between latitude 44° 45′ and 45° 30′ and longitude 75° 30′ and 76° 30′. Other airborne magnetometer surveys included those over a copper mine in western Ontario with flight lines spaced at 400-foot intervals and a survey in the Sudbury area of Ontario. Ground magnetometer surveys, especially for minerals, were also carried on extensively.

Field work for 1947 in the Gravity Division of the Dominion Observatory was carried on over widespread portions of Canada in nearly every province. Two field parties employing gravity and magnetic instruments were active. Observations were made with one party across Canada between Amherst, Nova Scotia, and Jasper, Alberta. Another gravity party occupied some 670 stations in northern Canada including an area of 185,000 square miles of the Canadian Shield. Observations were made with a vertical magnetometer at all gravity stations established by both parties except for two rail traverses in Ontario and Manitoba and about 400 stations in New Brunswick, where a considerable part of the area had previously been surveyed magnetically.

A very remarkable magnetic anomaly was encountered during the course of this survey over a distance of 40 miles between Gladstone and Minnedosa. A maximum of 10,000 gammas was observed and the gravity anomalies along this profile, although not as marked, nevertheless indicate a correlation with the magnetic results suggesting that the cause of the anomaly may be sought for in a dense magnetic rock.

Future plans in the Gravity Division include further observations in Ontario and Quebec and the establishment of tie-ins along the international boundary with proposed gravity surveys by Dr. George Woollard. He is planning to establish a network in the United States along the international boundary from the Atlantic to the Pacific under the auspices of The Geological Society of America.

RICHARD A. GEYER

Sequence in Layered Rocks by Robert R. Shrock. New York: McGraw-Hill Book Co., 1948. Pp. 483.

This book is divided into seven chapters dealing with criteria for determining top and bottom formations in layered rocks, especially in steeply inclined or vertical strata. The eighth chapter includes a very comprehensive bibliography totaling 737 references, many of which are referred to in some detail. The features discussed are divided into four categories, namely, gross relationships, features of sedimentary rocks, features of igneous rocks, and features of metamorphosed rocks. Those sedimentary features which are discussed are lithological-textural-mineralogical sequences, features on upper and undersurfaces of sedimentary beds, and internal sedimentary features. Igneous rocks are divided into the following categories: accumulation of volcanic ejectamenta, lava flows, plutons, sills and sheets, and dikes.

Proven procedures and methods for detecting stratification and false stratification for geographic locations from all over the world are given as examples for nearly every type of sequenced layers. This book also contains information concerning cyclic deposition successions, rhythmic sandstone-shale sequences, cycles, rhythms, cyclothems and megacyclothems, roof and floor of coal beds, features made on beaches by waves and tidal streams, raindrop and hailstone imprints, lava fragments, buried

boulders, coprolites and castings, mud cracks, fossils, buried trees, shell heaps and channel deposits. It should be of considerable help to the field geologist and the geophysicist versed in geology and is literally a geology library within itself having a detailed table of contents and three special indexes providing a quick and easy means of finding specific information. The 397 figures have added to the value of this work by furnishing illustrative and pictorial examples for determining top and bottom in layered rocks. The 650 diagrams and photographs were either drawn or reproduced by the author or obtained from other sources such as the Canadian and United States Geological Surveys and certain individual geologists or were published in other professional periodicals. They have all been duly acknowledged by Mr. Shrock.

MONA DENNIS GUILER

PUBLICATIONS RECEIVED

American Journal of Science, Vol. 246 No. 9 (September 1948), No. 10 (October 1948), No. 11 (November 1948)

American Petroleum Institute Quarterly, Vol. 18 No 4 (October 1948)

Annales de Geophysique, Tome 4, Annes 1948, Fasc. 1 (June 1948), Fasc. 2 (August 1948)

Annali di Geofisica (Istituto Nazionale di Geofisica, Rome), Vol. 1, No. 1 (Gennaio 1948), No. 3 (Luglio 1948)

Annotated Bibliography of Papers on Geochemical Prospecting for Ores, Circular 28 (August 1948)

"Auswertung Geophysikalischer Sondierungen mit Hilfe von Potentialfeldern" by F. Gassmann, Reprinted from *Erschienen in Schweiz Min. Petr. Mitteilungen*, Band XXVIII, Heft 1, 1948

Bulletin of the Seismological Society of America, Vol. 38, No. 3 (July 1948)

Proceedings of the Cambridge Philosophical Society, Vol. 44, Part 4 (October 1948)

Canadian Geophysical Bulletin, Vol. I, No. 1 (January–March, 1947), No. 2 (April–June, 1947), No. 3 (July–September, 1947), No. 4 (October–December, 1947), Vol. II, No. 1 (January–March, 1948)

Articles on Geophysics in Current Russian Periodicals, Lists 1 through 22. (Circular published by the Committee on the Geophysical Sciences of the Research and Development Board)

Economic Geology, Vol. XLIII, No. 5 (August 1948), No. 6 (September–October 1948), No. 7 (November 1948)

Geofisica Pura e Applicata, Vol. XII, Fasc. 5–6 (Luglio 1948), Vol. XIII, Fasc. 1–2 (Agosto 1948)

Geophysical Exploration (Society of Exploration Geophysicists of Japan), Vol. I, No. 1

Institute of Petroleum Review, Vol. 2, No. 19 (July 1948), No. 20 (August 1948)

"Interpretation of Electric Logs in Limestone" and "Electrical Logging Developments in the U.S.S.R." by Hubert Guyod (Reprint from *World Oil*, 1947–1948)

Journal of Applied Physics, Vol. 19, No. 8 (August 1948), No. 9 (September 1948), No. 10 (October 1948), No. 11 (November 1948)

Journal of the Chinese Geophysical Society, Vol. I, No. 1 (June 1948)

Journal of the Institute of Petroleum, Vol. 34, No. 295 (July 1948), No. 296 (August 1948)

Nafta, Roc. IV, Nr. 9 (Wrzesien 1948)

Naturwissenschaften—Mathematik Ingenieurwissenschaften Technik, October 1948

Quarterly of the Colorado School of Mines, Vol. 43, No. 3 (July 1948)

Quarterly Journal of the Geological Society of London, The, Vol. CIV, Part 1 (August 1948)

Review of Scientific Instruments, The, Vol. 19, No. 8 (August 1948), No. 10 (October 1948)

Revista Geomineraria, Geologia e Geofisica Applicate, Anno IX, No. 1, 1948

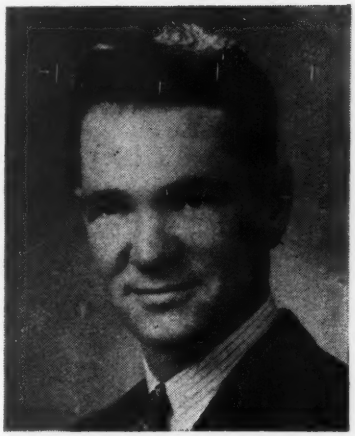
"Temperature Well Logging" by Hubert Guyod (Reprint from *The Oil Weekly*)

Terrestrial Magnetism and Atmospheric Electricity, Vol. 53, No. 3 (September 1948)

World Petroleum, September, October and November, 1948

The publications listed above are available to members on request to the Business Manager.

CONTRIBUTORS



G. A. BURTON

G. A. BURTON received his B.A. degree in physics from the University of California at Los Angeles in 1937. He was employed as a research engineer at Rieber Laboratory until the fall of 1938. Since that time he has been engaged in seismic interpretation for the Shell Oil Company, Inc. in California and the Rocky Mountain area.

He is a member of the Society of Exploration Geophysicists, the American Geophysical Union, and the Wyoming Geologic Association.

B. G. SWAN

B. G. SWAN received a Bachelor of Science degree in geological engineering from the University of Oklahoma in 1932, after having spent parts of the three preceding years in geophysical field work with the Continental Oil Company. He returned to Continental in the fall of 1932 and has remained with that company since that time. His experience has been primarily in the various phases of seismic interpretation and supervision, and at present he is Superintendent of Seismic Operations in the Geophysical Department at Ponca City.

Mr. Swan is a member of the Society of Exploration Geophysicists and the American Association of Petroleum Geologists.

HOMER JENSEN

HOMER JENSEN, Chief of the Magnetometer Division of the Aero Service Corporation, began his work with the airborne magnetometer in 1943 at the Naval Ordnance Laboratory. As project engineer for geophysical tests of the instrument, he helped make the first survey in March, 1944. In 1945 he aided in surveys in Iron County, Michigan; Naval Petroleum Reserve No. 4 in Alaska; and in the first Shoran-guided survey, in the Gulf of Mexico.

At Aero he has directed magnetic surveys in the United States, Canada, the Bahamas, and the survey which the company is making for the Mozambique-Gulf Oil Company in Portuguese East Africa.

W. RAYMOND GRIFFIN graduated from Baylor University in 1936 with an A.B. degree in physics. Following a two-year fellowship in mathematics at Texas A. and M., he received the M.S. degree in that subject. He then taught mathematics in the high schools of the state for two years. In 1940 he became associated with Curtiss-Wright at St. Louis as a stress analyst. After a half year he was transferred to the Flutter and Vibration Group as a Vibration Engineer. He served in this capacity until June, 1945. In the following month he joined Robert H. Ray Company as their Research Geophysicist which position he continues to hold.

Mr. Griffin is a member of the Society of Exploration Geophysicists, American Geophysical Union, and the Institute of Aeronautical Sciences.

W. RAYMOND GRIFFIN

MARTIN C. KELSEY received his B.S. degree in geology from Southern Methodist University in 1931. Prior to his graduation he was employed by Geophysical Service, Inc. to compute experimental electrical measurements in the exploration for oil. From 1931 to 1947 he worked with Geophysical Service, Inc. as computer, Party Chief, and Interpretation Supervisor. In 1947 he was instrumental in organizing the Rayflex Exploration Company, of which company he is now president.

Mr. Kelsey is a member of the American Association of Petroleum Geologists and the Society of Exploration Geophysicists.

MARTIN C. KELSEY

HARRY L. THOMSEN

HARRY L. THOMSEN received his A.B. degree in mathematics from Oberlin College in 1932 and his M.A. degree in geology from the same school in 1934. During the following year, as a teaching fellow at the University of California, he continued graduate work in geology.

Mr. Thomsen has been employed by Shell Oil Company, Inc. since 1935 in various phases of geophysical and geological work in California and the Rocky Mountain region. At present he is Division Geophysicist and Acting Division Geologist of Shell's Colorado Division in Denver.

He is a member of Sigma Xi, the Society of Exploration Geophysicists, the American Geophysical Union, the Seismological Society of America, and the American Association of Petroleum Geologists.

In addition, references are cited to earlier issues for the biographies of: C. Hewitt Dix, Vol. XIII, No. 1 (January, 1948), Raoul Vajk, Vol. XII, No. 2 (April, 1947), L. W. Gardner. Vol. XII, No. 2 (April, 1947).

SOCIETY ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following candidates for membership in the Society. This publication does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it to the President within thirty days. (Names of references appear in parentheses after the name of each nominee.)

ACTIVE

Stanley Randolph Allen (H. G. Patrick, M. M. Slotnick, J. E. LaRue)
Robert Watson Bauer (I. M. Griffin, C. H. Gerdes, M. W. Harding)
Arnaldo Belluigi (C. A. Heiland, E. Kogbetliantz, B. Gutenberg)
Mario Bossolasco (J. A. Fleming—non-member, J. B. Macelwane, B. Gutenberg)
Weston Bourret (J. J. Jakosky, W. S. Olson, C. H. Wilson)
Arthur Whitwell Black (B. G. Swan, L. F. Athy, H. R. Prescott)
Gabor Dessau (W. D. West—non-member, further reference waived by Executive Committee)
Philip Donnerstag (R. C. Barker—non-member, W. H. Young, Jr., W. Heroy Jr.)
Elmer Harrison Finch (H. B. Peacock, E. McDermott, E. Fain)
John C. J. Fuller (A. F. Beck, P. M. Tucker, C. H. Acheson)
Robert Benjamin Galeski (W. L. Matjasic, L. H. Metzner, R. A. Peterson)
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Homer Lafayette Heggy (C. H. Green, K. E. Burg, P. P. Gaby)
Hugh Cooke Hotchkiss (P. M. Tucker, A. F. Beck, C. H. Acheson)
John Philip Hughes (W. H. Courtier, A. J. Hintze, J. E. Bondurant)
Glen Wallace Ledingham (P. F. Clement, E. H. Vallat, Morris Muskat)
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Ernest Edward Opitz (E. Watts, J. E. Taylor, W. M. Wells)
Byron Gordon Ownby (O. C. Clifford, Jr., C. H. Hightower, A. E. McKay)
James Carlton Porter (R. P. Warren, H. G. Patrick, D. H. Gardner)
Thomas Charles Poulter (R. P. Green, S. Harris, M. B. Dobrin)
Robert Jennings Riggs (R. C. Coffin, T. A. Manhart, J. A. Sharpe)
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Jesse Emory Spencer (R. H. Tucker, D. B. Winfrey, L. C. Spencer)
Pierre Louis Taranger (E. G. Leonardon, E. F. Stratton, J. C. Legrand)
Samuel A. Teasley (J. E. LaRue, H. G. Patrick, J. W. Bolinger)
Warren Calvin Thackston, Jr. (R. P. Warren, H. G. Patrick, S. D. O'Brien)
Dick Louie Thomas (C. C. Hutchinson, J. F. Anderson, Sidney Schafer)
David Richard Weichert (A. B. Bryan, E. J. Handley, G. E. Wagoner)

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Charlie Beryl Autrey (W. W. Newton, J. E. Jett, B. D. Farrow)
Richard A. Campbell (R. L. Suggs, J. D. Todd)

Chester Woodward Chamberlin (O. C. Clifford Jr., A. E. McKay, C. H. Hightower)
Jenner Kent Chance (J. R. Woolson, K. A. Robertson, N. J. Christie)
David Allen Davis (L. J. Peters, L. D. Palmer, R. D. Wyckoff)
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Wesley Stanley Johnson (R. F. Bennett, Donald Crary, E. B. Stewart)
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Kasmier Dominic Kubik (A. B. Hamil, R. W. Upshaw, Gorden Mace)
Ramon Kyle (C. M. Moore Jr., R. C. Dunlap Jr., C. H. Green)
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Rowell Lansen Nash Jr. (A. B. Hamil, R. W. Upshaw, B. K. Johnson)
Archibald John Nicol (C. H. Green, C. M. Moore Jr., Ross Henderson)
George Gust Pagonis (Eugene Cronin, R. S. Jackson, John Wilson)
Alfred Ernest Pallister (F. H. Agee, M. W. Harding, P. K. Bhattacharya)
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Wylye Parker Robertson Jr. (Robert Dyke, Dean Walling, Henry Salvatori)
Louis George Rodrigue Jr. (A. B. Hamil, R. W. Upshaw, Byron Johnson)
Milton Higdon Rogers (R. A. Walters, Arne Junger, L. I. Freeman)
Clarence H. Sandberg (K. L. Cook, H. R. Joesting)
Louis Evans Schneider (A. E. McKay, C. H. Hightower, Harding Butt)
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Halliday Winfield Shoupe (Paul Farren, J. A. Gillin, R. D. Bryan)
Lee Simpson (Sidon Harris, P. H. Ledyard, E. L. Fetzer)
Jerzy Sosnowski (E. van der Linden, H. H. Brons, A. A. Fitch)
Carlton Thomas Spalding (R. H. Ray, J. C. Pollard, J. B. Nichols)
John William Stanfield (J. P. Woods, H. L. Cobb, O. C. Clifford Jr.)
Dorothy Ann Steele (H. L. Cobb, E. L. DeLoach, O. C. Clifford Jr.)
John Stewart Sumner (L. O. Bacon, B. H. Boyum, W. A. Longacre)
Paul Louis Pierre Terrasson (F. Goldstone, L. K. Mower, O. B. Manes)
Leslie Lee Vaughan (R. F. Bennett, Donald Crary, E. B. Stewart)
Gordon Harry Weisser (R. F. Weichert, J. A. Armstrong, C. J. Chapman)
Rayburn H. Whitt (C. J. Donnally, Dean Walling, David Sheffet)
William August Williges (Dean Walling, Robert Dyk, Henry Salvatori)
David Grinnell Willis (W. H. Myers, M. W. Harding, Herbert Hoover Jr.)
Edward Karol Franciszek Zarudzki (Noel Frost, A. A. Fitch, E. van der Linden)
Robert Allen Boulware (W. H. Amis, K. H. Waters, Paul Farren)

TRANSFERS

Ross E. Brannian (Student to Assosiate)

George R. Rogers (Student to Associate)

REINSTATEMENT

Erik Helmer Hedstrom (Charter Member)

RESIGNATION

J. J. H. Jansen (Associate)

STUDENT

The applications of the candidates for Student Membership listed below have been approved by the Secretary-Treasurer. According to the Bylaws, Article III, Section 5 (as amended), "In the case of applicants for Student Membership, publication is not required. The Student Member shall be pronounced elected when approved by the Secetary-Treasurer."

Thomas Patrick Anderson
Robert Wilkes Baldwin
William Davisen Black
Wayne Forrest Bohanan
Frederick Charles Boyd
Norman Arthur Carter
Clifford Marvin Chappell
John Dowsett
John B. Etnyre
Michael Morson Fitzpatrick
Ronald Frank Harris
Brian Bernard Hill
Mary Jane James
William Sweitzer King
Samuel Anthony LaGreca
Eric Best Manchee
Donald Richard Martin
Thomas Owen May
Calvin Floyd Neill
William Kerr Rankin
Michael Stephen Reford
Robert James Searls
David Thomas Shaw
Russell William Stephenson
Robert James Uffen
Donald Maxwell Wagg
John Patrick Walter
Stanley Harry Ward
Thomas Canby Woodward

PAPERS PRESENTED AT MEETINGS OF LOCAL SECTIONS

DALLAS GEOPHYSICAL SOCIETY

September 13 1948

Safety Regulations in Seismic Operations, A. E. McKay, Atlantic Refining Co., Chairman of the S.E.G. Safety Committee.

October 19 1948

Case History of Magnolia Oil Field, Columbia County, Arkansas, L. C. Spencer (read by Richard Brewer) and Jack Peters, Atlantic Refining Company and Magnolia Petroleum Company, respectively.

November 18–19, 1948: Dallas Regional Exploration Meeting

1. *History of the Continental Shelf of the Gulf of Mexico*, Paul Weaver, Gulf Oil Corporation, Houston.
2. *What is a Reef?* Ronald K. DeFord, University of Texas.
3. *Geophysical Exploration for Limestone Reefs*, F. J. Agnich, Geophysical Service Inc., Dallas.
4. *The Barrier Reef Theory*, E. Russell Lloyd, Consulting Geologist, Midland.
5. *Limestone Development in the Pennsylvanian of the Eastern Permian Basin*, Frank B. Conselman, Consulting Geologist and J. N. Conley, Seaboard Oil Company, Abilene.
6. *Jameson Field, Coke County, Texas*, W. H. Conkling, Sun Oil Company, Midland.
7. *A Precision Detail Gravity Survey of the Jameson Area, Coke County, Texas*, Hart Brown, Brown Geophysical Company and Geophysical Associates, Houston.

8. *Shoran as a Surveying Method for Marine Geophysical Exploration*, Carl H. Keller, the Atlantic Refining Company, Morgan City, La.
9. *Elimination of Seismic Shot Holes*, Thomas C. Poulter, Stanford Research Institute, Stanford, California.
10. *Pennsylvanian Reef at Todd Field, Crockett County, Texas*, Robert F. Imbt, Consulting Geologist, Ft. Worth, and S. V. McCollum, Continental Oil Co.
11. *Pennsylvanian Reef Lawson-Chapman Area, Haskell County, Texas*, Walter L. Ammon, Stanolind Oil and Gas Co., Wichita Falls, Texas.
12. *The Dundee Area, Archer County, Texas—Sand Production Related to the Pennsylvanian Reef*, Jack E. Kadane, Independent Operator, Wichita Falls.
13. *The Vealmoor Field, Howard County, Texas—A Pennsylvanian Reef*, S. J. Taylor and H. C. McCarver, Seaboard Oil Company, Dallas.
14. *The Kleiner Mississippian Pool, Eastland County, Texas*, Philip G. Russell, Lone Star Gas Company, Dallas.
15. *Distribution of Heterostegina Lime, Fannett Field, Jefferson County, Texas*, Howard Hough, Gulf Oil Company, Houston.
16. *Microstructure and Behavior of the Sediments*, Eugene McDermott, P. E. Haggerty and Gale White, Geophysical Service Inc., and W. R. Ransone, E. C. Reagor of Geochemical Surveys, Dallas.
17. *A Seismic Problem of Faulting*, M. W. Quarles, United Geophysical Company, Dallas.
18. *A Seismic Problem Encountered Across Faults*, E. J. Stulken, Geophysical Service Inc., Dallas.

S.E.G. HOUSTON SECTION

September 30, 1948

Microstructure and Behavior of the Sediments, Eugene McDermott, Geophysical Service Inc., Dallas.

October 28, 1948

Case History of the Salem Oil Field, Illinos, A. A. Hunzicker, The Texas Company, Houston.

PACIFIC COAST SECTION S.E.G.

October 28–29, 1948: Annual Fall Meeting

The annual fall joint society meeting was held at the Huntington Hotel, Pasadena, California. A series of geophysical papers were given during the forenoon of October 28. Maynard W. Harding, chairman of the program committee, and Curtis H. Johnson, president of the Pacific Coast Section, were co-chairmen of the meeting. The following papers were presented:

1. *The Correlation of Gravity Anomalies with Seismic and Geological Data in California*, P. F. Clement, Western Gulf Oil Company, Bakersfield, and G. R. Watson, Gulf Research and Development Company, Pittsburgh, Pa.
2. *Review of Some Wartime Studies of Explosive Phenomena*, R. A. Peterson, United Geophysical Company, Pasadena.
3. *A New System of Seismic Exploration*, Thomas C. Poulter, Stanford Research Institute, Stanford, California.
4. *The Oscillatory Character of Seismic Pulses*, C. Hewitt Dix, California Institute of Technology, Pasadena.
5. *Philippine Exploration Problems*, J. L. Soske, Geophysical Engineering Corporation, Pasadena.
6. *Comparative Interpretation of Airborne and Surface Magnetometer Data*, Wayne Hoylman, Fairchild Aerial Surveys, Inc., Los Angeles.
7. *The Blast Damage Claim Racket*, H. M. Engle, Structural Engineer, San Francisco.

A luncheon meeting of the society was held on Friday, October 29 for reports from committee chairmen and from the secretary-treasurer. T. P. Ellsworth, chairman of the tellers committee, announced the election of officers for the coming year as follows:

President: R. C. Dunlap Jr., Geophysical Service Inc., Bakersfield.
Vice President Southern District: C. Hewitt Dix, California Institute of Technology, Pasadena.
Vice President Northern District: J. C. Waterman, Shell Oil Company Inc., Bakersfield.
Secretary-Treasurer: W. D. Cortright, Tide Water Associated Oil Company, Bakersfield.

Guest of honor was Dr. L. L. Nettleton, who discussed at some length the business of the national society, and conveyed greetings of the national officers.

W. D. CORTRIGHT
Secretary-Treasurer, Pacific Coast Section

ARK-LA-TEX GEOPHYSICAL SOCIETY, SHREVEPORT, LOUISIANA

September 20, 1948: Joint meeting with Shreveport Geological Society

Geophysical Prospecting by Telluric Currents, E. G. Leonardon, Geolectric Corporation, Houston, Texas.

October 14, 1948

Prospecting for Petroleum, a 23-minute color moving picture produced by George Pal under supervision of Shell Oil Company, Inc.

November 15, 1948: Joint meeting with Shreveport Geological Society and A.I.M.E. East Texas

Shoran Surveying, Robert L. Suggs, Offshore Navigation, Inc., Houston, Texas.

GEOPHYSICAL SOCIETY OF TULSA

October 14, 1948

Microstructure and Behavior of the Sediments, Eugene McDermott, Geophysical Service Inc. Dallas, Texas.

November 11, 1948

A New Seismic Shooting Technique, Thomas C. Poulter, Stanford Research Institute, Stanford, California.

December 10, 1948

Symposium: *The Effect of Instruments on Interpretation*, E. M. McNatt, The Carter Oil Company; W. T. Born, Amerada Petroleum Corp.; J. E. Hawkins, Seismograph Service Corp.

January 14, 1949

Symposium: *The Geological Correlation of Seismic Events*, led by H. M. Thralls, Seismograph Service Corp.

COLORADO SCHOOL OF MINES SOCIETY OF STUDENT GEOPHYSICISTS

October 4, 1948: Organization meeting

The first meeting of the season was presided over by Robert Shaller, president of the society. Social and membershlp committees were appointed, and the objects of the society were explained to students applying for membership. Ralph Holmer, faculty advisor, read a letter from the Society of Exploration Geophysicists advising that the society has been affiliated with the national organization. Professor Holmer also reported on the speakers whom he had contacted for future meetings.

November 1, 1948

What the Employer Expects of the Employee, R. L. Fitzgerald, Atlantic Refining Company.

November 8, 1948

Exploration for Oil by Geology and Geophysics, a film presented by John T. Geer, Magnolia Petroleum Company, Dallas, Texas.

December 9, 1948

The Role of the Magnetometer in the Oil Industry, Jack W. Peters (Mines, 1938), Magnolia Petroleum Company, Dallas, Texas.

April 22, 1949: Engineering Day

The 15th annual Engineer's Day of the Colorado School of Mines will be held in Golden, Colorado on Friday, April 22, 1949.

The program will feature speakers on many phases of the mineral industries as well as exhibits and scholarship examinations.

Exhibition space, both indoors and out, is available, free of charge, to all industries engaged in or related to the discovery, extraction, and refining of minerals and petroleum. Exhibitors must, however, assemble and take down their displays. Potential exhibitors are reminded that the day affords an excellent opportunity to acquaint future mineral engineers as well as many alumni and visitors with their products and organizations.

Complete information concerning any point of the day's activities may be obtained by writing J. Robert Medaris, Chairman of the Engineering Day Committee, Golden, Colorado.

C. W. BOWLBY
Secretary-Treasurer
Colorado School of Mines Society of
Student Geophysicists

UNIVERSITY OF TULSA STUDENT GEOPHYSICAL SOCIETY

December 3, 1948

A Magnetic Survey of the Owasso Dome is the title of a paper presented by William J. Cunningham, Vice-President of the student geophysical society, at the meeting of the Oklahoma Academy of Science held on the campus of The University of Tulsa. The Oklahoma Academy is an affiliate of the American Association for the Advancement of Science.

This survey is being conducted as a laboratory project by the Geophysics 80 class at the university under the direction of Professor V. L. Jones.

REPORT OF THE SECRETARY-TREASURER
AMENDMENTS TO THE CONSTITUTION

Tabulation of the vote on the ballot of Amendments to the Constitution and Bylaws of the Society (GEOPHYSICS, Vol. XIII, No. 3—July 1948—page 515) was completed August 26, 1948. A summary of the voting appears in the table below; a favorable majority was received by all amendments.

Amendment	*Yes*	*No*	*No Vote*	*Total*
A	457	43	8	508
B	484	20	4	508
C	479	25	4	508
D	475	14	19	508
E	490	14	4	508
F	454	19	35	508
G	483	14	11	508
H	455	48	5	508
I	468	16	24	508

The Constitution and Bylaws, as amended, will appear in GEOPHYSICS, Vol. XIV, No. 2 (April 1949).

E. V. MCCOLLUM
Secretary-Treasurer

ANNOUNCEMENTS

ACKNOWLEDGMENT

The Memorial to Frank Rieber (1891–1948) which appeared in GEOPHYSICS, Vol. XIII, No. 4 (October 1948), was written by Curtis H. Johnson. Through an error in the Business Office, the customary "by-line" was omitted.

FOURTH EMPIRE MINING AND METALLURGICAL CONGRESS

The Fourth Empire Mining and Metallurgical Congress, convened by the Empire Council of Mining and Metallurgical Institutions, will be held in Great Britain in July, 1949. The program will be divided into three parts: July 9 to 12—Inaugural Meeting, official functions, exhibitions, visits, etc. in London; July 13 to 17—Technical Sessions in Oxford; July 18 to 23—A number of excursions based for the most part on universities in Great Britain. The chief object of the Congress is to afford an opportunity for scientists, engineers, and others concerned with the mining and metallurgical industries, to meet and discuss technical progress and problems. Further information may be obtained by writing to: The General Secretaries, Fourth Empire Mining and Metallurgical Congress, 436, Salisbury House, Finsbury Circus, London, E.C. 2.

NEW ROCK-COLOR CHART NOW AVAILABLE

The new Rock-color Chart is now available and can be purchased from the Division of Geology and Geography, National Research Council, Washington 25, D. C. for $5.50 per copy. This chart is designed especially for field use but is suitable also for use in the office or laboratory. It consists of 8 sheets, 5 by 7½ inches, and will fit conveniently in the back of a field notebook. It includes 115 colors which indicate the range of rock colors for all purposes, and a brief text explains the system used for the chart arrangement and the color names.

The color names have been chosen to agree with the ISCC-NBS system—National Bureau of Standards Research Paper RP 1239, now under revision—which is already accepted by a large number of scientific organizations. The choice was designed to select a system of simple rock-color names (such as *dark reddish brown*) sufficiently standardized to be acceptable to color scientists and sufficiently useful to be satisfactory to both field and laboratory geologists.

The form and arrangement of the chart are based on the Munsell system, the most widely accepted system of color identification in the United States. In addition to the color names, the Munsell numerical designation is placed under each color for the use of those geologists who wish to make fine color distinctions by interpolation between the colors shown on the chart.

GEOPHYSICS AND GEOGRAPHY COMMITTEE CHAIRMAN NAMED

Dr. W. E. Wrather, director of the Geological Survey, Department of the Interior, has been named chairman of a Committee on Geophysics and Geography by Dr. Karl T. Compton, chairman of the Research and Development Board, National Military Establishment. The committee met on December 3.

The newly formed committee is a merger of the Committee on Geophysical Sciences and the Committee on Geographical Exploration, two units of the Research and Development Board. The group will study problems within the scope of the earth sciences, including weather and climate, strategic minerals, water supplies and contamination, studies of the ocean, its circulation, and structure of the ocean floor.

The committee will consider exploration expeditions and other types of field research. Its agenda includes the geographical nature and use of areas of the earth's surface with emphasis on the effect of physical and cultural elements of environment on man and his activities. Map content and coverage also will be studied.

Additional members of the committee include Mr. Samuel B. Morris, General Manager and Chief Engineer of the Department of Water and Power, Los Angeles; Dr. Horace Byers, Department of Meteorology, University of Chicago; Dr. P. E. James, Professor of Geography, Syracuse University; and Dr. Richard Joel Russell, Chairman, Department of Geography, Louisiana State University, Baton Rouge, La.

Alternates to members include Mr. W. W. Rubey, Geological Survey, alternate to Dr. Wrather; Dr. Athelstan Spilhaus, Dean, School of Technology, University of Minnesota, alternate to Dr. Byers; Dr. Stephen B. Jones, Institute of International Studies, Yale University, alternate to Dr.

James and Dr. Lester E. Klimm, Chairman, Department of Geography, Wharton School, University of Pennsylvania, alternate to Dr. Russell.

Members to represent the three military services will be named shortly.

Dr. H. E. Landsberg, formerly deputy executive director of the Committee on Geophysical Sciences will be executive director.

TECHNICAL SYMPOSIUM FOR ELECTRONIC ENGINEERS IN GEOPHYSICS

A series of technical symposia of interest to the electronic engineers in geophysics is being planned for presentation in Houston during the coming winter months. Now in preparation, the first of these meetings will be a round-table discussion of A.V.C. Amplifiers for Geophysical Applications. The date of the first meeting was tentatively scheduled for Monday, November 22. Topics for later meetings will be selected to meet the needs and wishes of the group.

The technical symposia are being conducted as a joint project of the American Institute of Electrical Engineers, The Society of Exploration Geophysicists, and The Institute of Radio Engineers. The primary purpose of the meetings is to bring together for group study and discussions the electronic specialists scattered throughout various geophysical laboratories of the petroleum industry. It is hoped that a program of this kind will operate not only for the technical development of the individuals but that it will stimulate the writing and publication of technical papers, the development of standards, and a wider exchange of technical knowledge and methods. Following a trial period in Houston, it is planned to initiate similar meetings in other cities where there are geophysical laboratories.

Details regarding the technical symposia will be announced hereafter through the local sections of the sponsoring societies in Houston. Further details or notices of the meetings may be secured by writing either William M. Rust, Jr. of the Humble Oil and Refining Company, Houston, or Laurence G. Cowles of the Superior Oil Company, Bellaire, Texas.

PERSONAL ITEMS

S. PRESTON WEATHERBY has resigned as Geophysicist for Southern Minerals Corporation to open his own office in Corpus Christi as consulting geophysicist to specialize in the review interpretation of seismic data of the Southwest Texas Area.

SYLVAIN J. PIRSON has joined the engineering department of Stanolind Oil and Gas Company as Research Reservoir Engineer. He was Professor of Geophysics in the School of Mineral Industries of The Pennsylvania State College until January of this year. His address will be Box 591, Tulsa 2, Oklahoma.

J. ROBERTSHAW is now a director of Geophysical Services Limited of 2, Lord North Street, London, S.W. 1. The company is mainly concerned with the application of electrical and magnetic methods to civil engineering problems, and the location of ground-water supplies.

A. P. CRARY has taken a leave of absence from Watson Laboratories of The U. S. Air Forces, and is now with United Geophysical Company at Awali, Bahrein Island.

WILLIAM A. LONGACRE of the physics department, Michigan College of Mining and Technology, has recently been promoted to the rank of professor. Professor Longacre also holds the position of consulting geophysicist with the Cleveland-Cliffs Iron Company.

H. L. RASÉ, JR. has been appointed seismic party chief for Gulf Research and Development Company, and is now located at Shawnee, Oklahoma.

"FROM HERE TO THERE"

HERBERT G. RIM, from Santa Barbara, California to Box 1086, Houma, La. G. J. BLUNDUN, from Canadian Gulf Oil Co., to Northwest Seismic Services, 1910-12th Ave. W., Calgary, Alberta. URAL A. ROWE, from Lamesa, Texas to 2514 Gulf Building, Houston 2, Texas. R. L. KRETZ, from Worland, Wyoming to 5115 Shoshone, Denver, Colo. R. G. SOHLBERG, from Menominee, Michigan, to "c/o Richmond Exploration Co.," Aptdo. 93, Maracaibo, Venezuela. D. F. COOLAUGH, from Jardine, Montana to 1700 Maple St., Golden, Colo. A. D. DUNLAP, from Houston to 1411 Electric Bldg., Ft. Worth, Tex. GORDON E. BOWLER, from Alhambra, Calif. to 8033 Emerson Ave., Los Angeles 45, Calif. T. C. RICHARDS, from London to "c/o Australasian Petroleum Co. Ltd.," Port Moresby, New Guinea. C. D. KEEN, from Leland, Mich. to 529 Robinson Pl., Shreveport 21, La. JOHN W. BOLINGER, from Houston to P. O. Box 3327, Corpus Christi, Tex. J. C. HEGGBLOM, from Nassau, Bahamas to "c/o Mozambique Gulf Oil Company," Caixa Postal No. 69, Lourenco Marques (Mozambique), Portuguese East Africa. LEWIS C. CRIDER, from New Orleans to P. O. Box 1680, Wichita Falls, Tex. GEORGE G. SHOR, JR., from Lovington, N. M., to Box 306, Seminole, Texas.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1933

of GEOPHYSICS, published quarterly at Menasha, Wisconsin, for January, 1948

State of Oklahoma } ss.
County of Tulsa }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Colin C. Campbell, who, having been duly sworn according to law, deposes and says that he is the business manager of GEOPHYSICS, and that the following is, to the best of his knowledge and belief, a true statement of ownership, management (and if a daily, weekly, semiweekly or triweekly newspaper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the act of August 24, 1912 as amended by the acts of March 3, 1933, and July 2, 1946 (section 537, Postal Laws and Regulations), printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Society of Exploration Geophysicists, P. O. Box 1614, Tulsa 1, Oklahoma; Editor, Dr. M. King Hubbert, 3737 Bellaire Blvd., Houston 5, Texas; Managing Editor, Dr. M. King Hubbert, 3737 Bellaire Blvd., Houston 5, Texas; Business Manager, Colin C. Campbell, P. O. Box 1614, Tulsa 1, Oklahoma.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.) Society of Exploration Geophysicists, P. O. Box 1614, Tulsa 1, Oklahoma; L. L. Nettleton, President, 1348 M. Esperson Bldg., Houston 2, Texas; Andrew Gilmour, Vice-President, Box 2040, Tulsa 1, Oklahoma; Cecil H. Green, Past President, 6000 Lemmon Ave., Dallas 9, Texas; E. V. McCollum, Secretary-Treasurer, 515 Thompson Bldg., Tulsa 3, Oklahoma.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given: also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

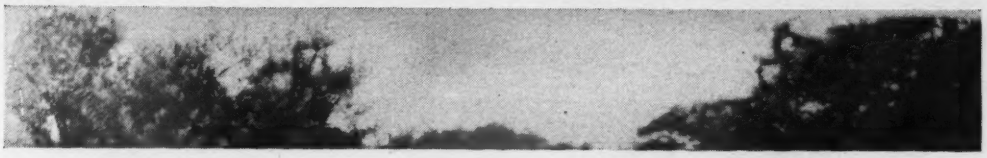
5. That the average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the twelve months preceding the date shown above is not required. (This information is required from daily, weekly, semiweekly, and triweekly newspapers only.)

COLIN C. CAMPBELL (Signed)

Sworn to and subscribed before me this 8th day of October, 1948.

[SEAL] MYRTLE E. GRIMMETT (Signed)

(My commission expires May 22, 1951.)



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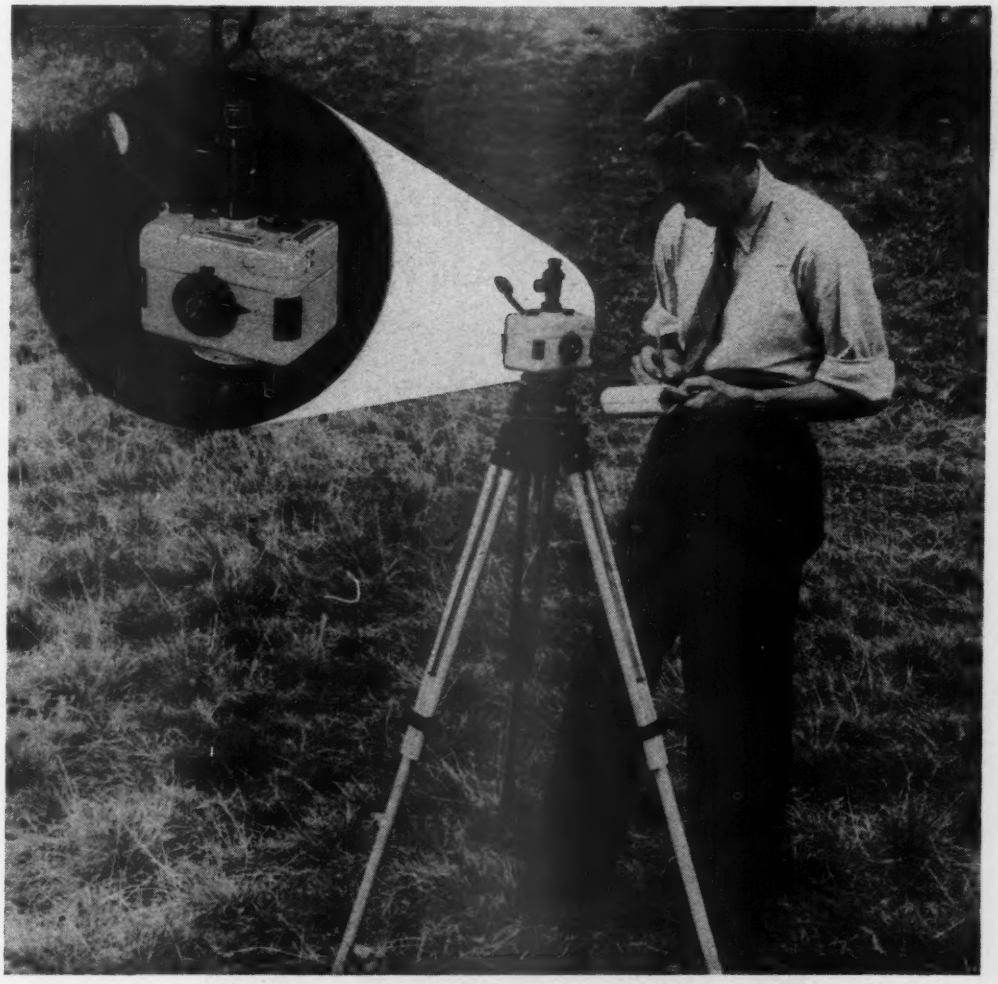

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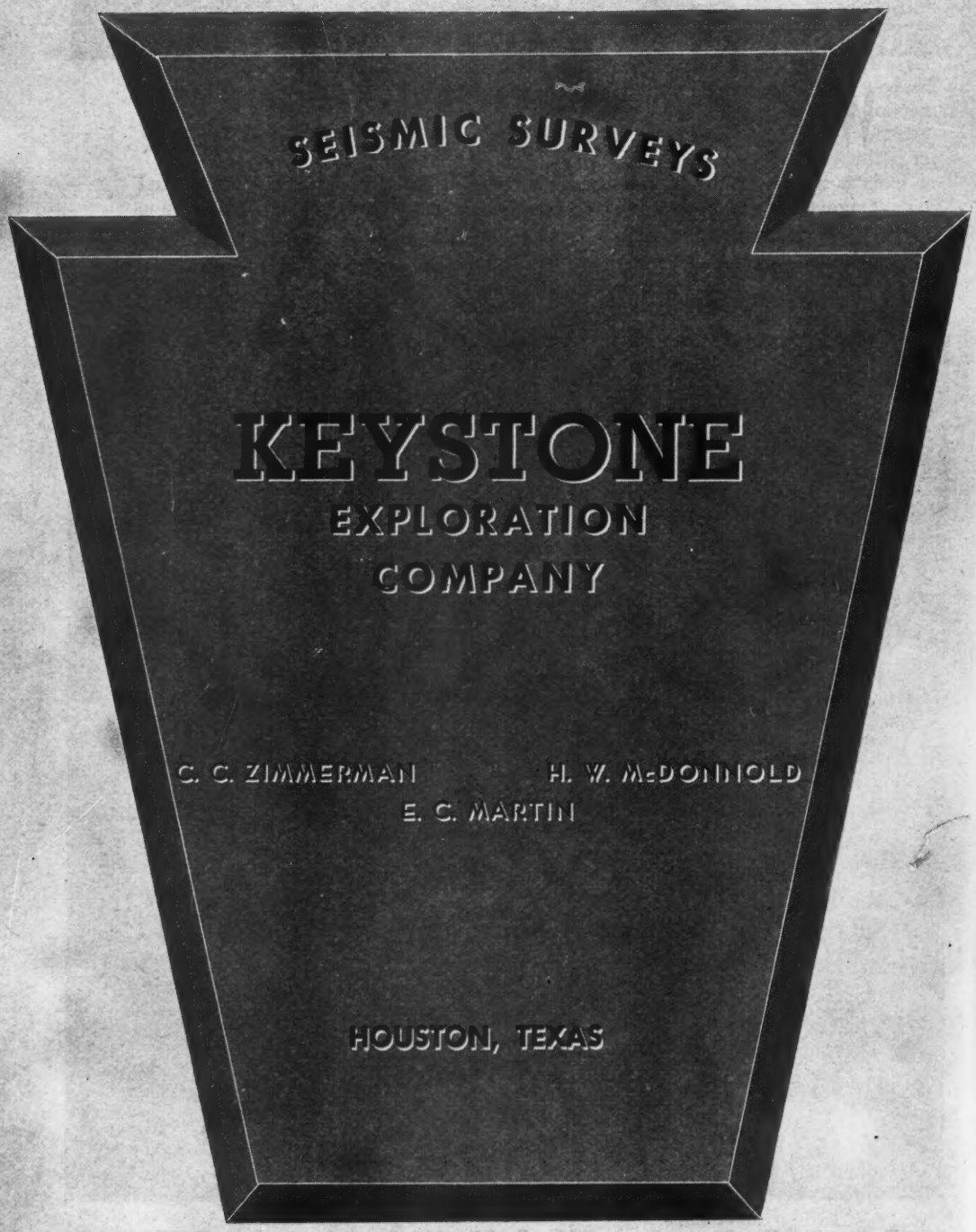
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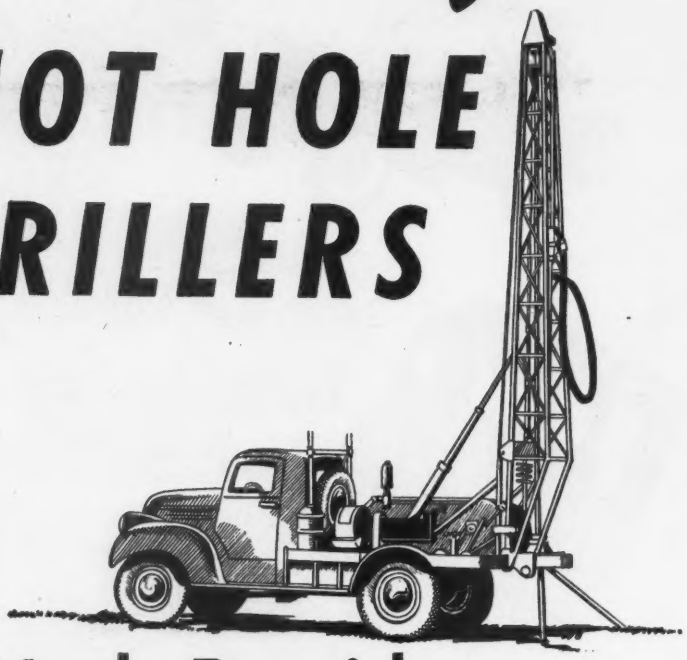

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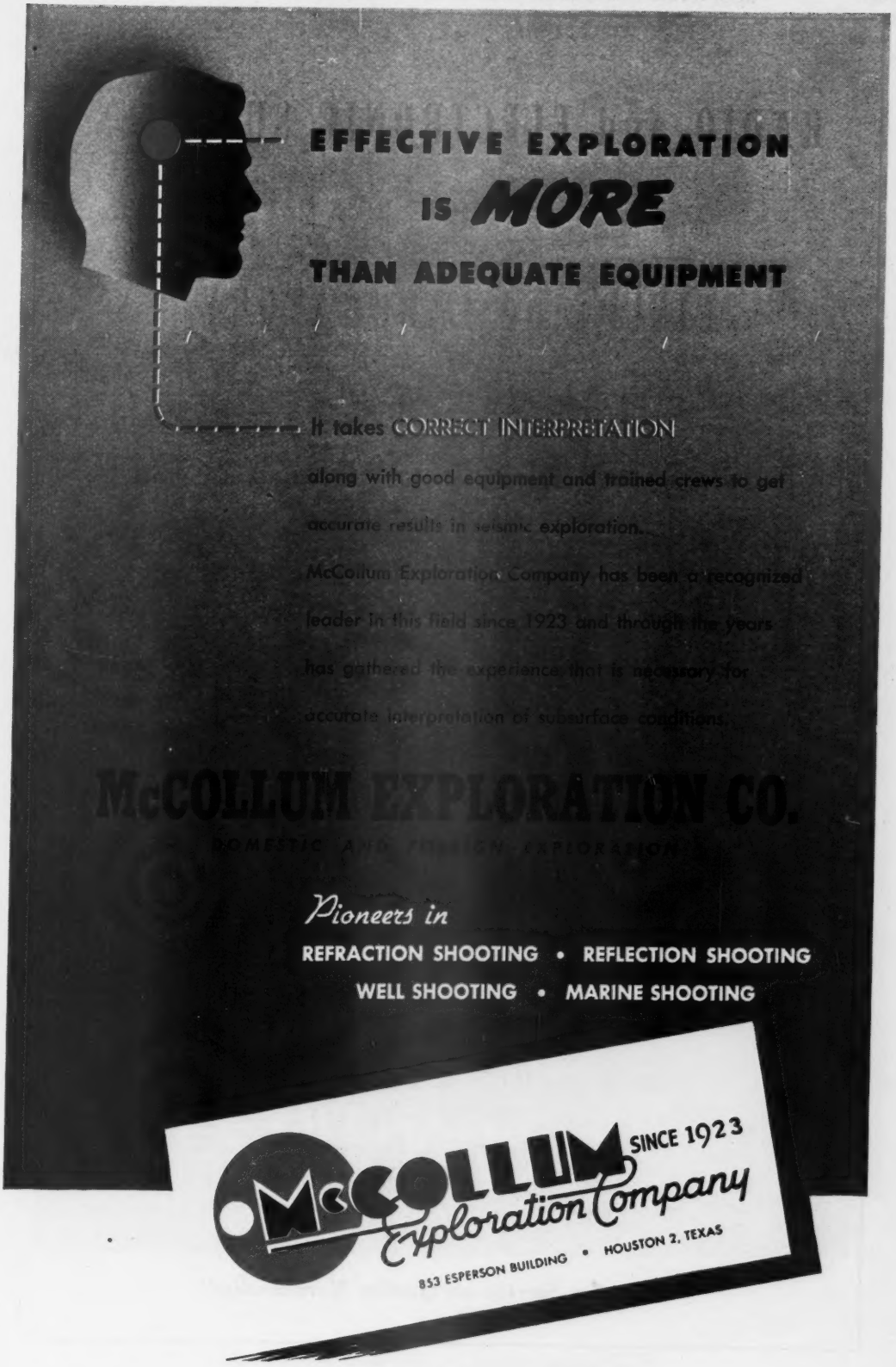
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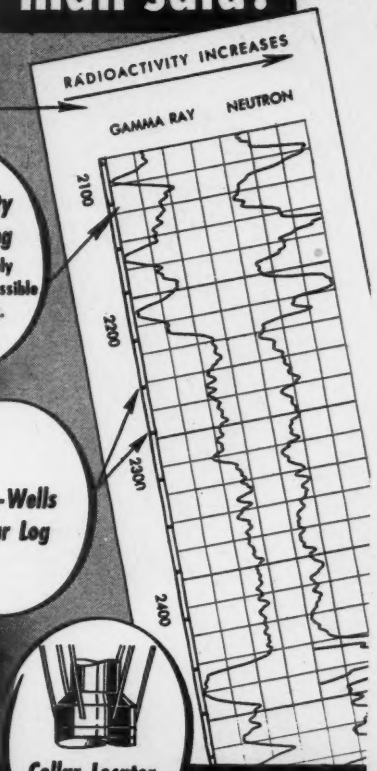

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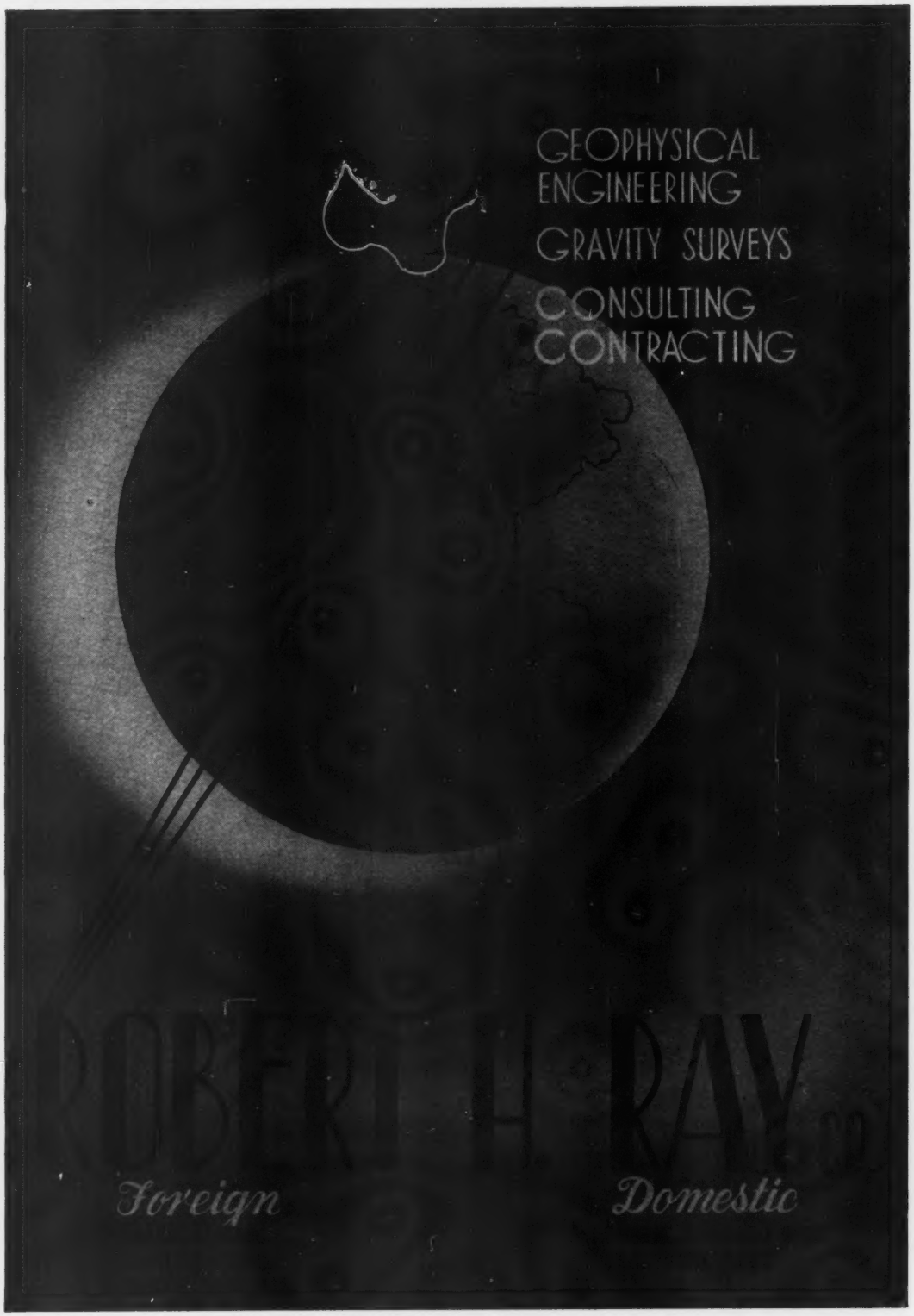
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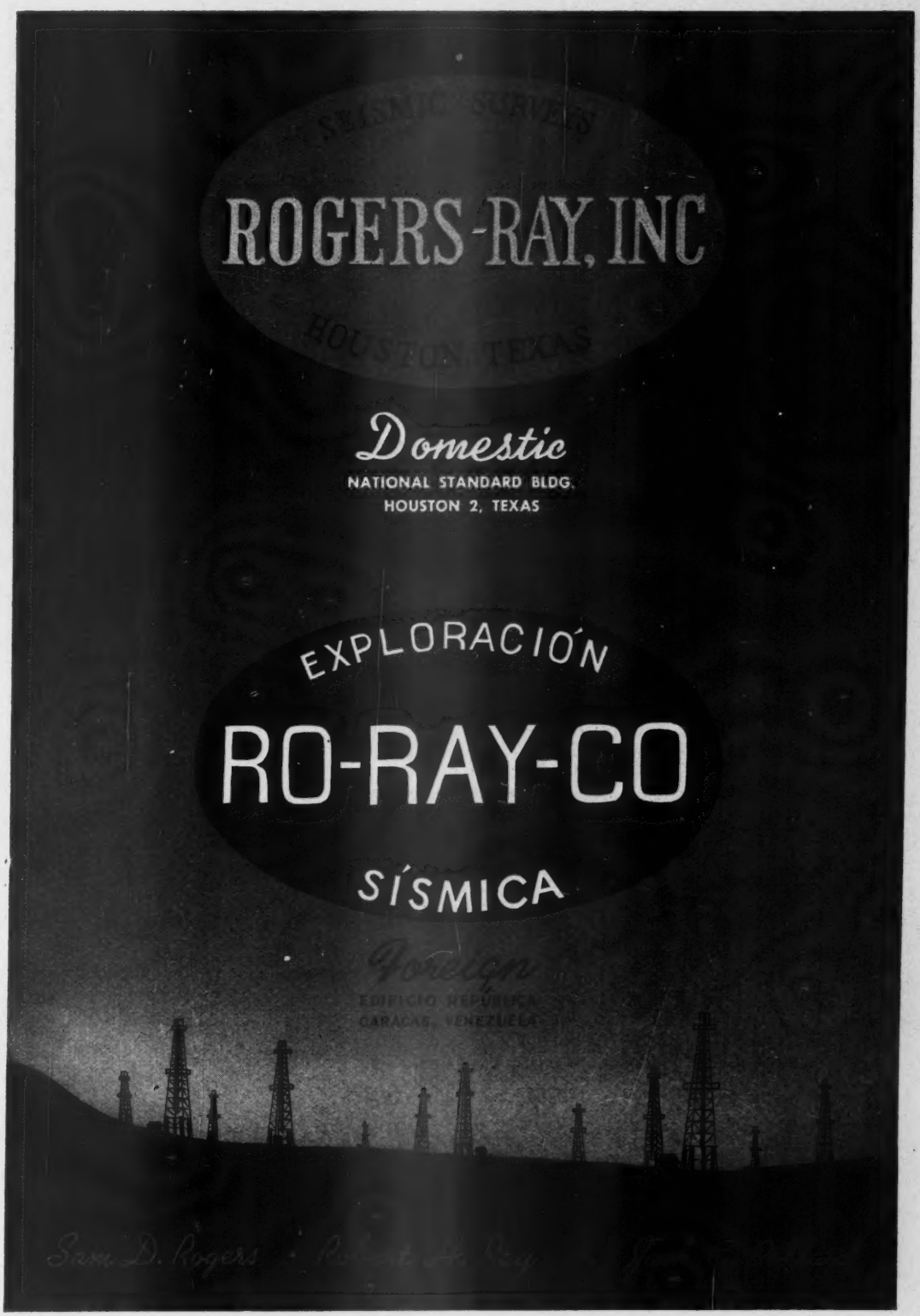

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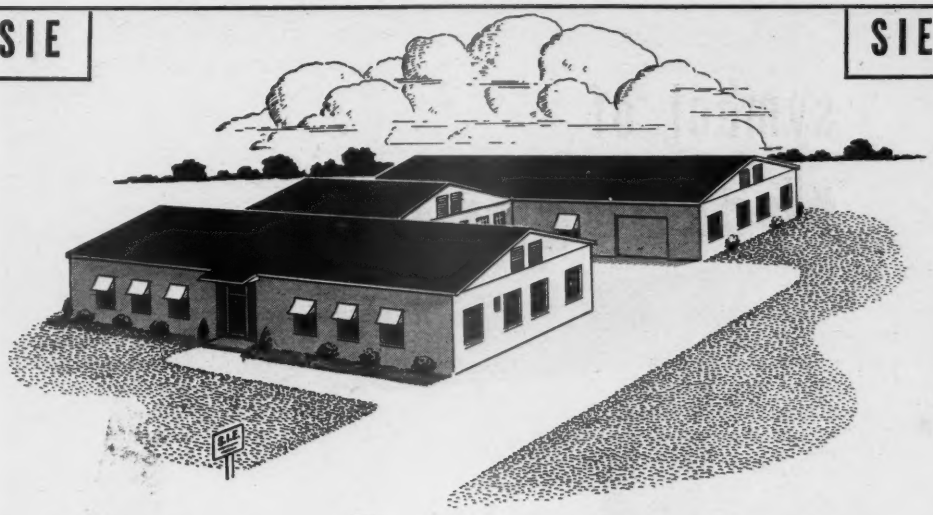

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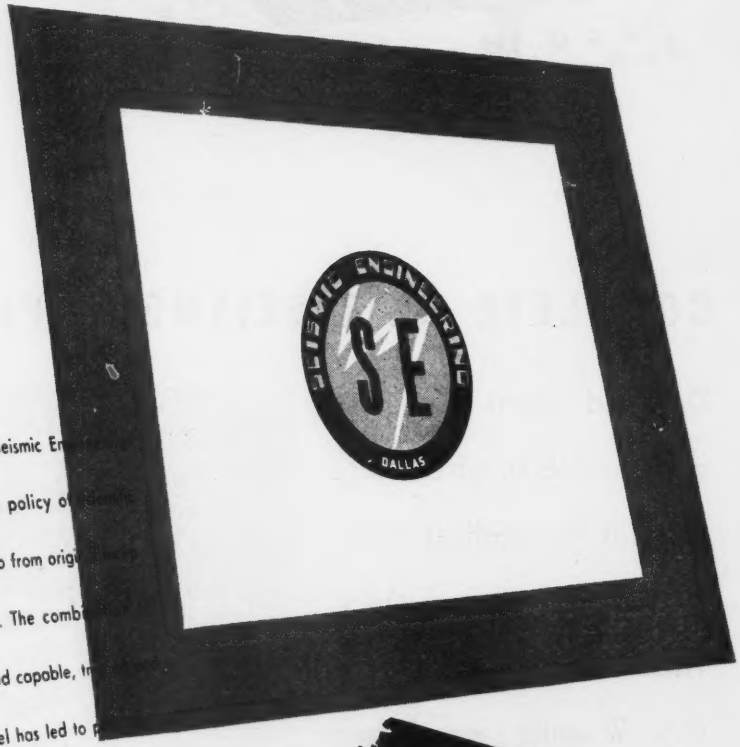

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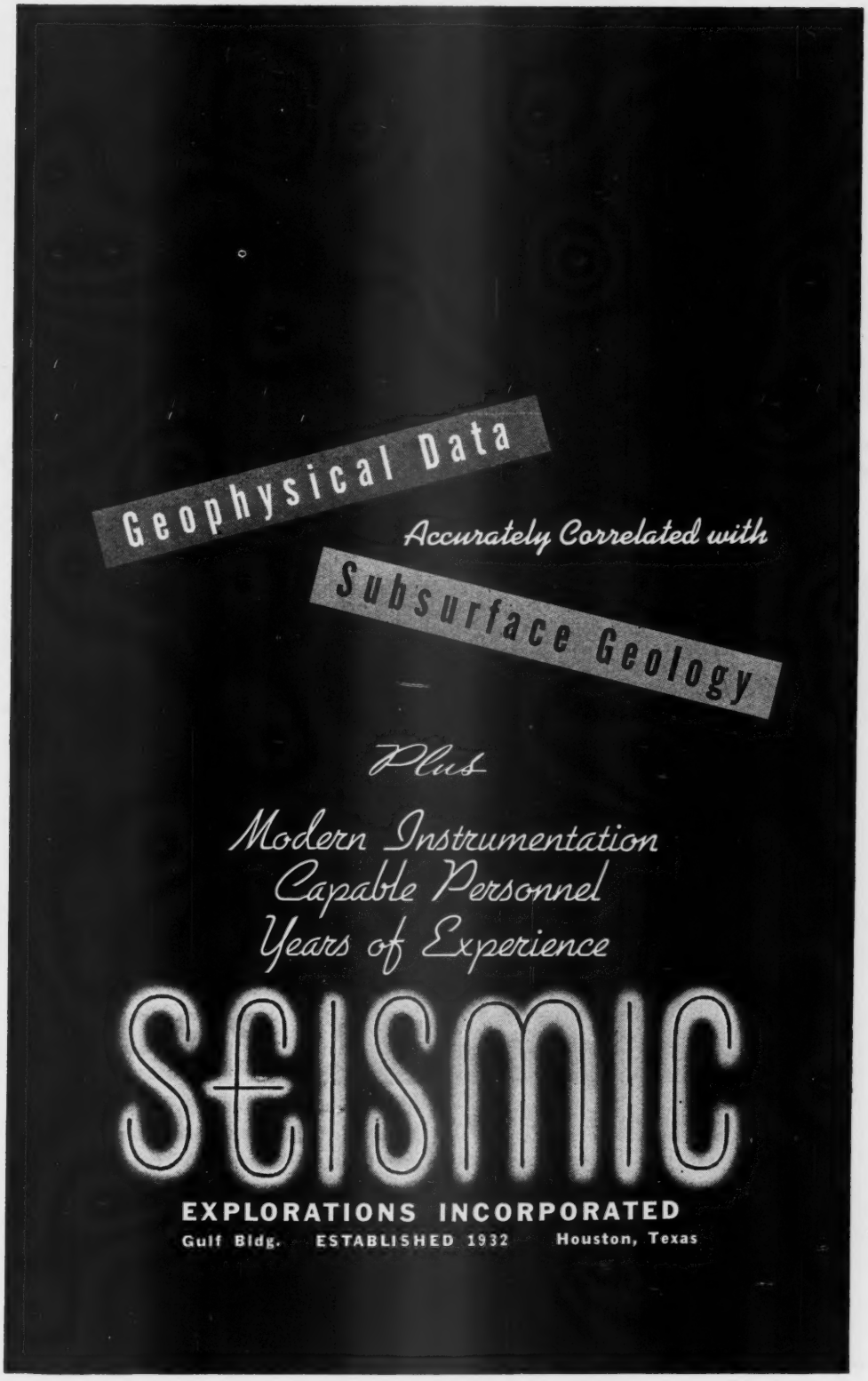
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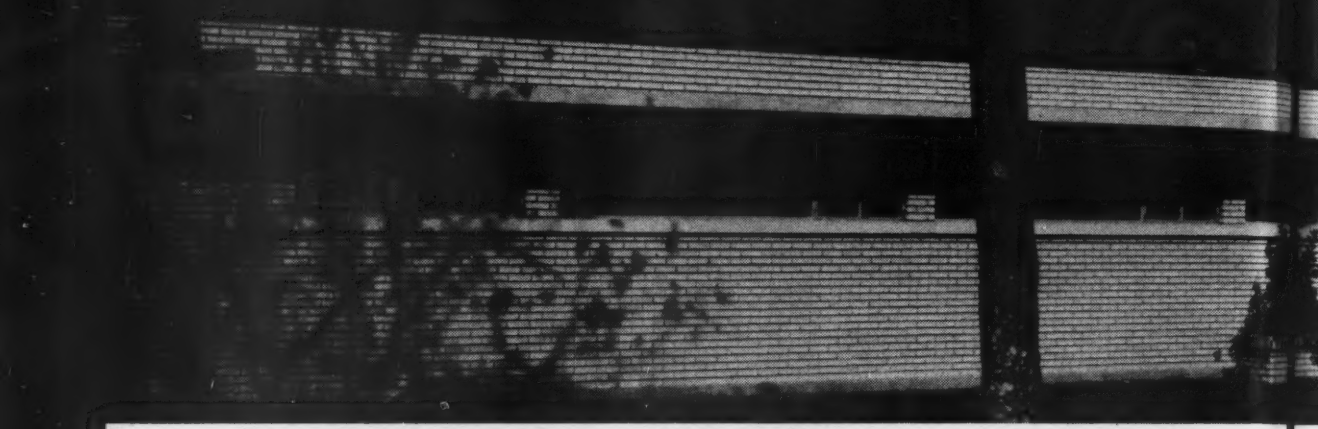

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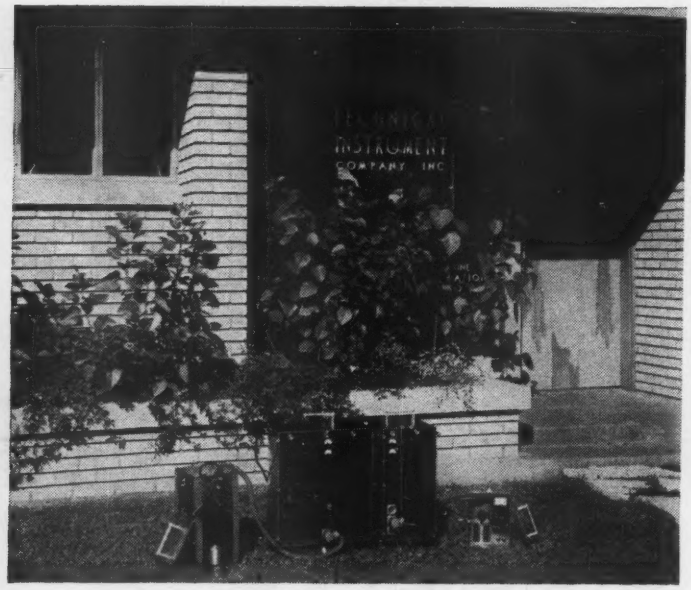

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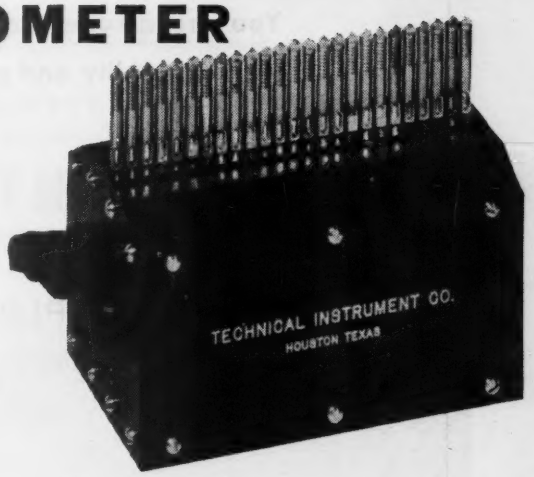

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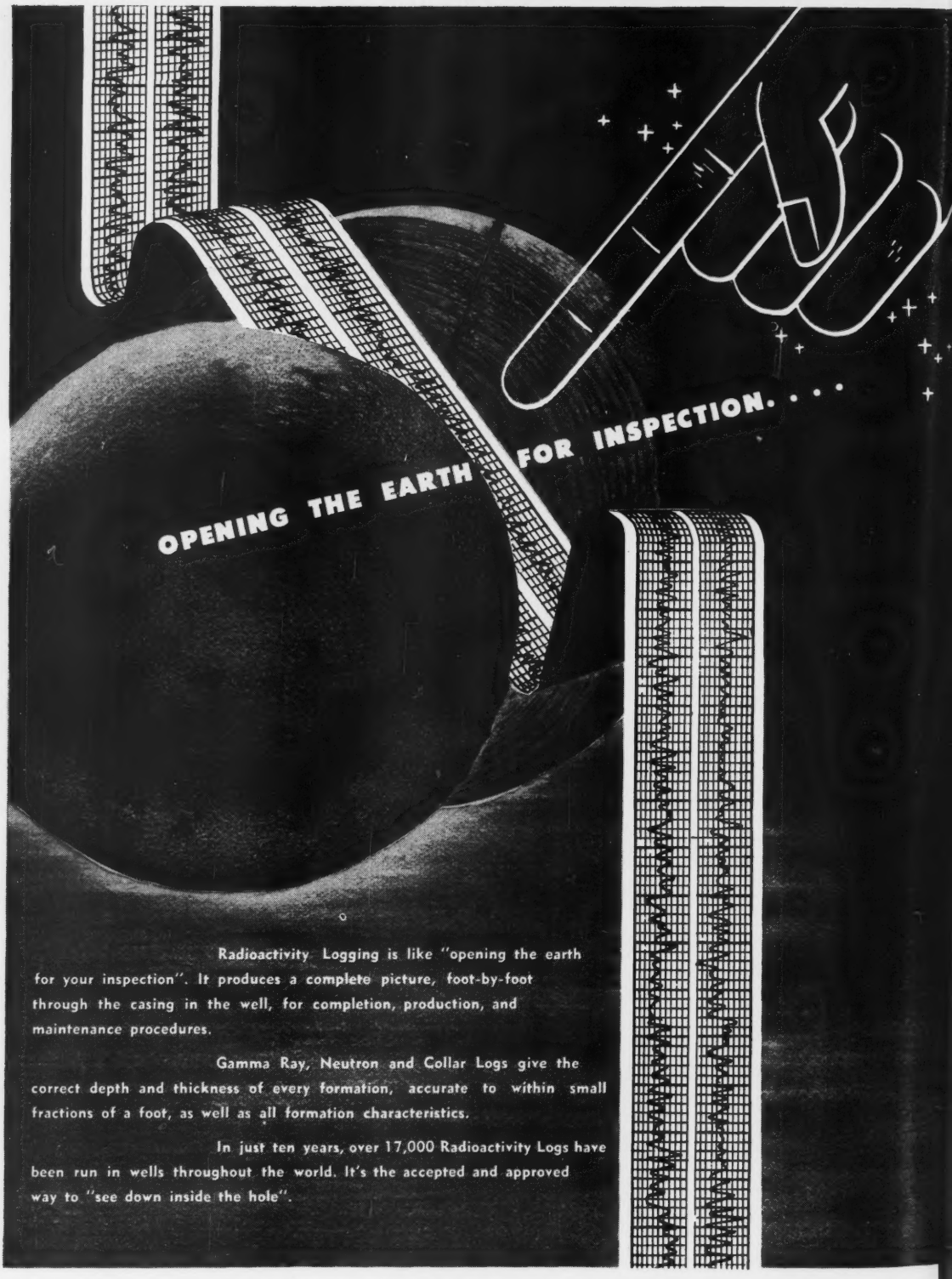

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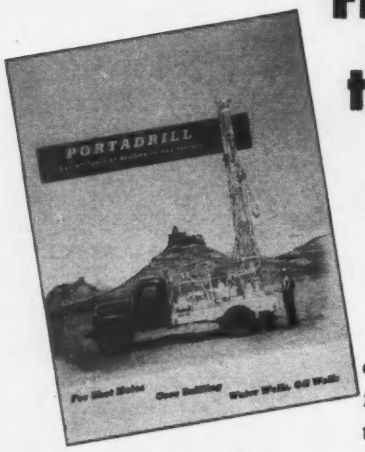

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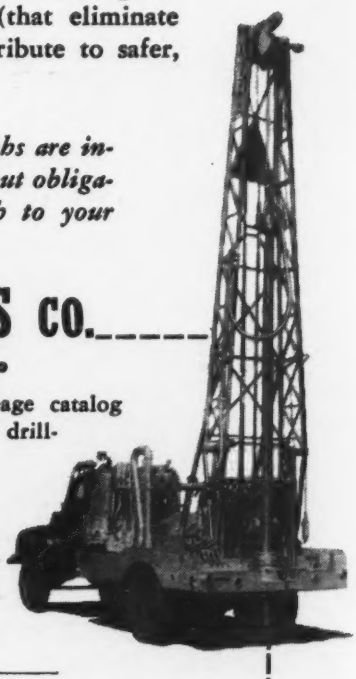

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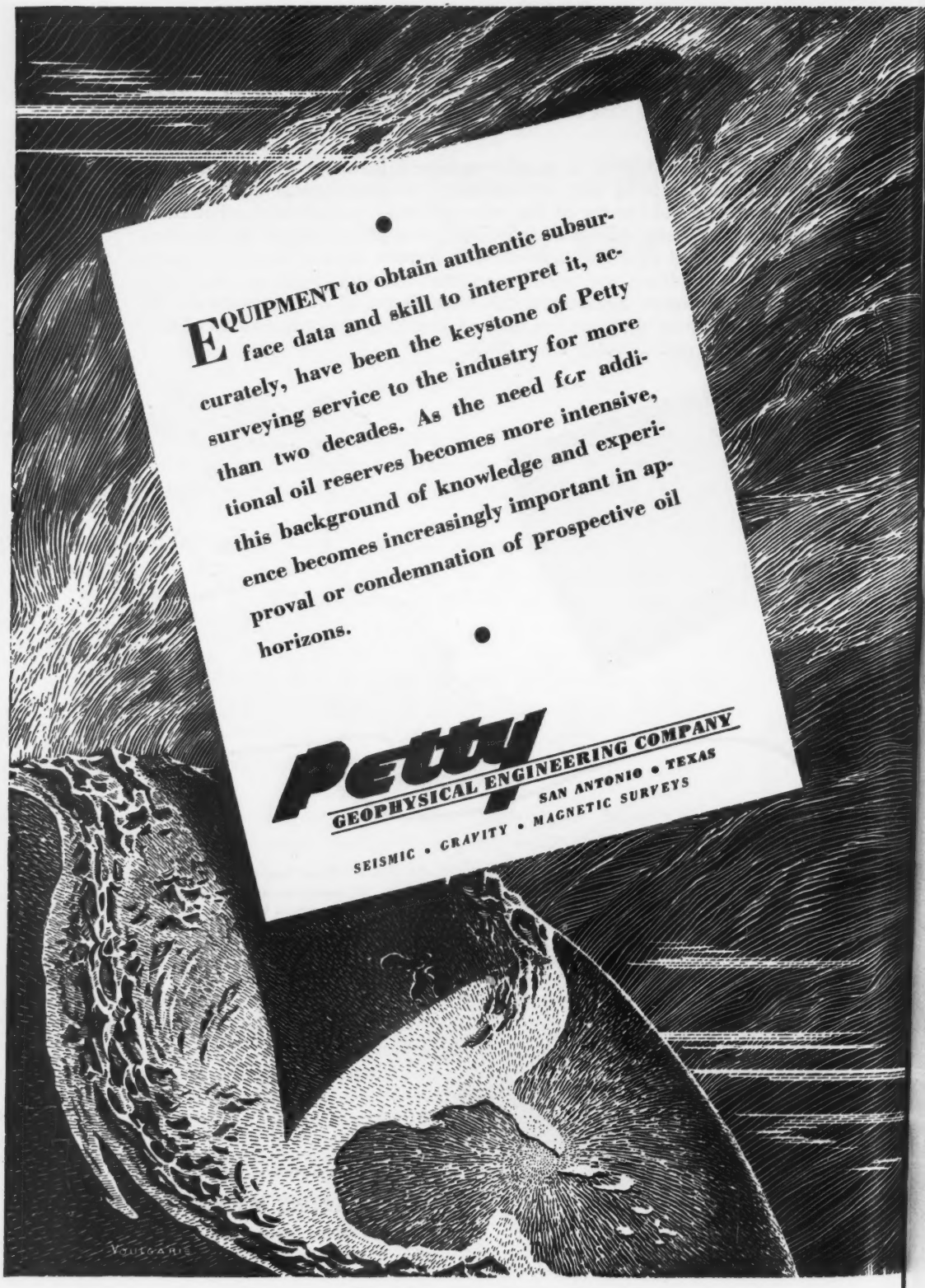
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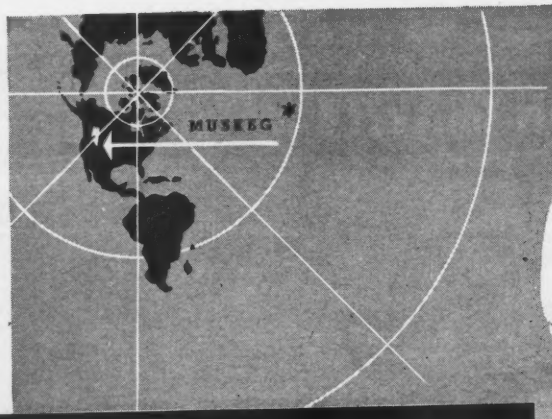

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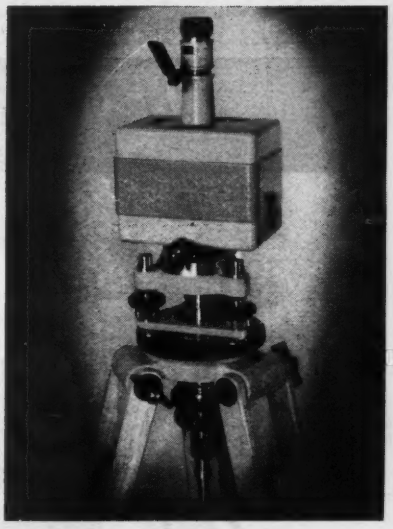

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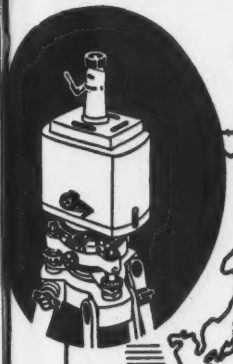

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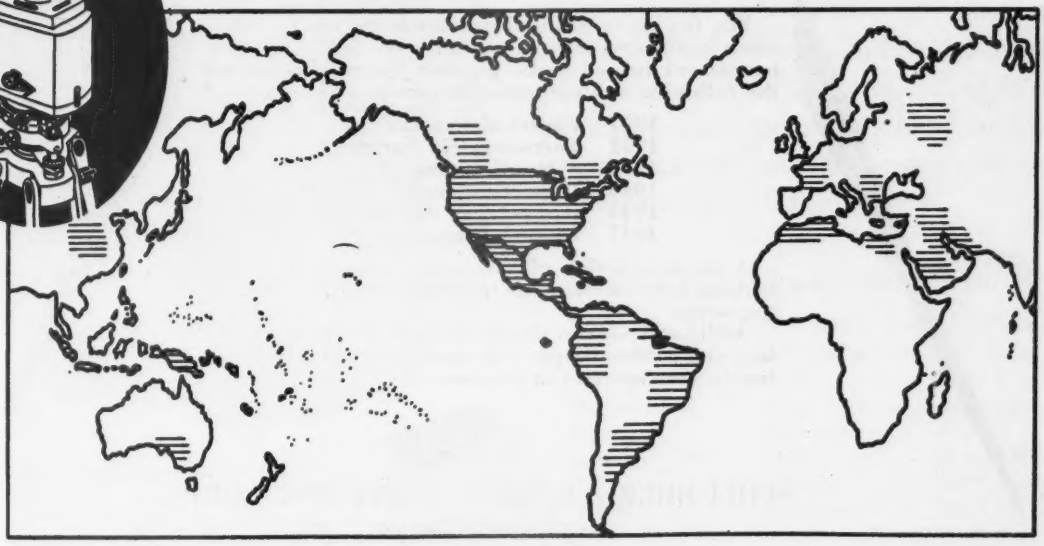

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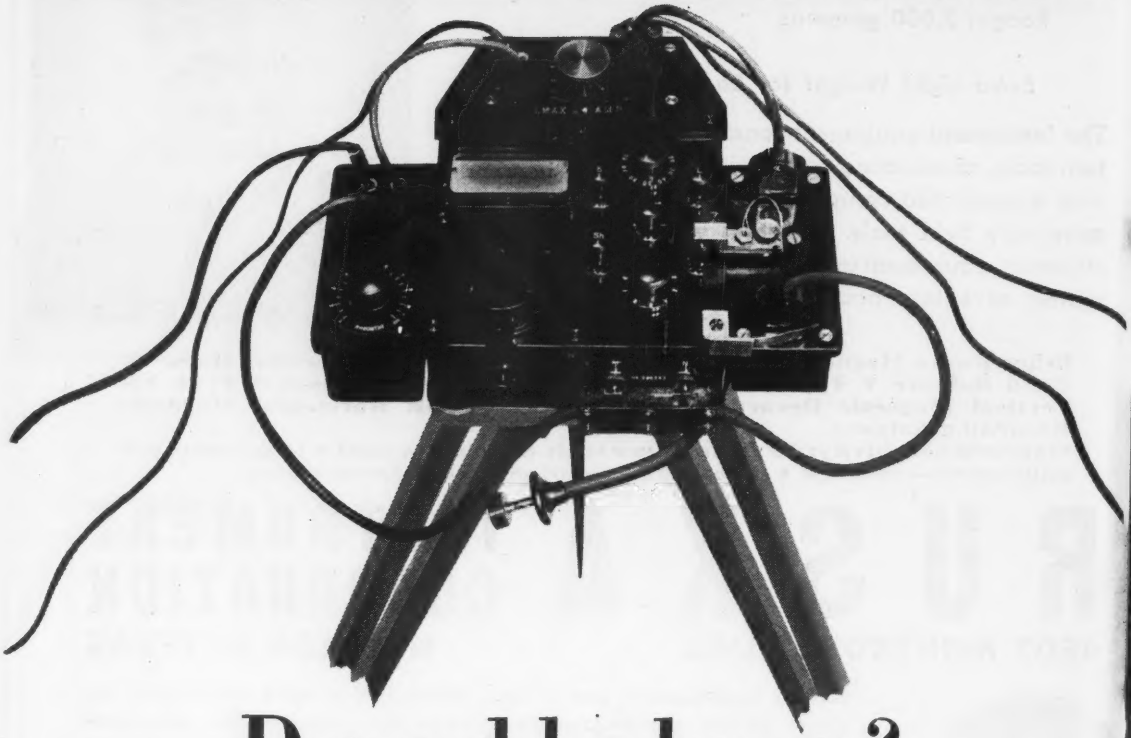
The Schlumberger Story

CHAPTER THREE



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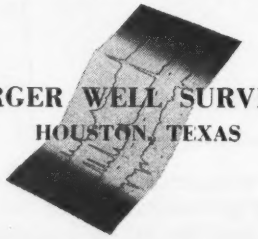

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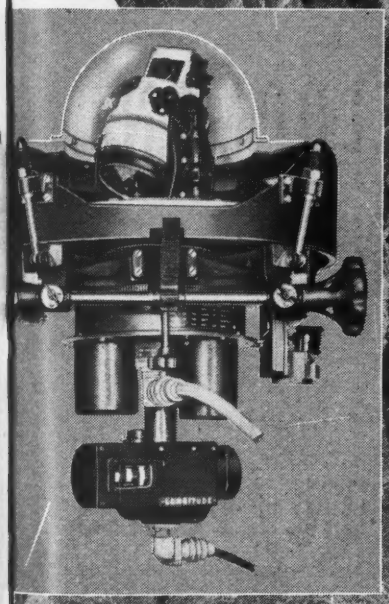

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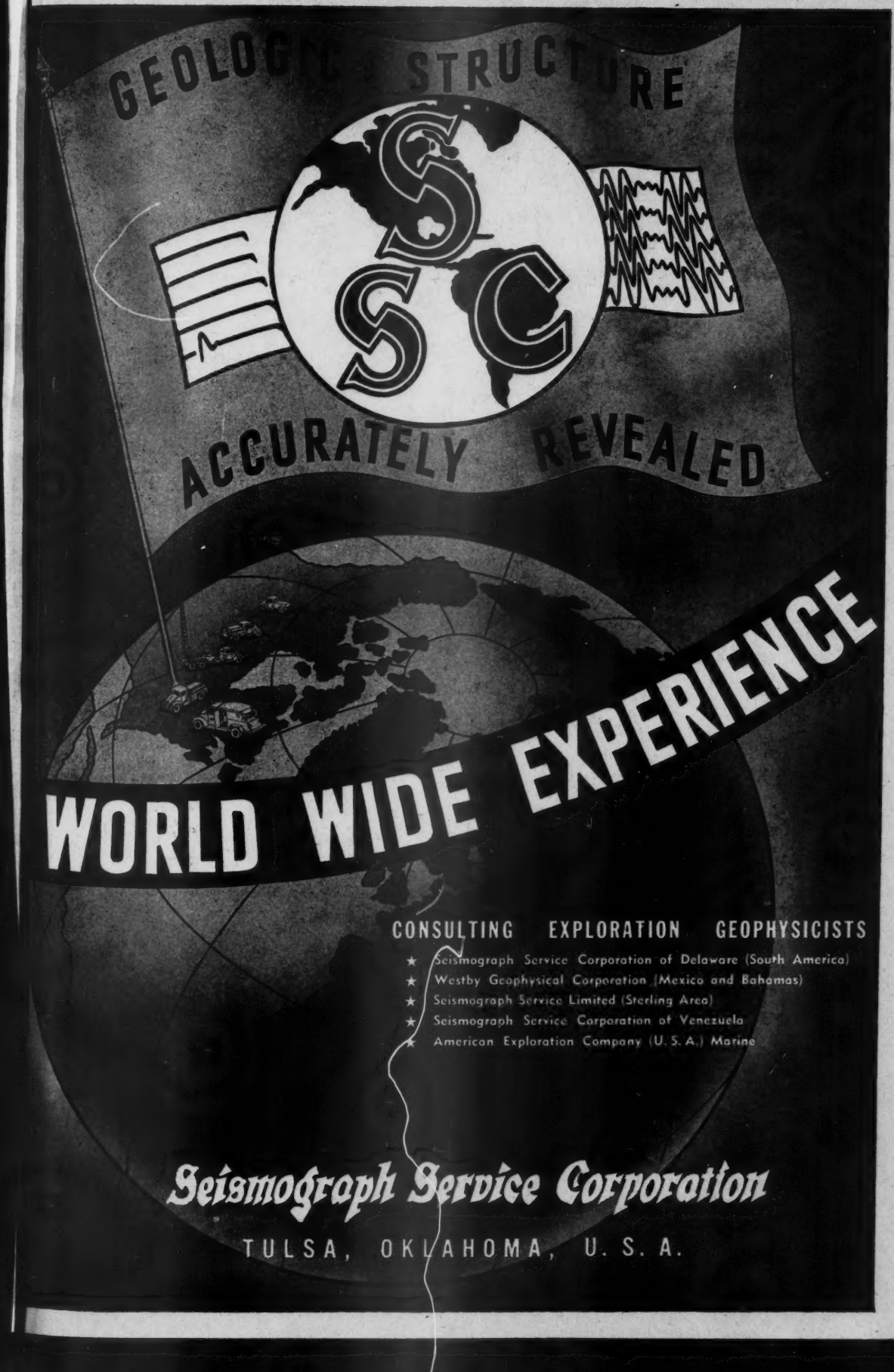
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